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EVERY-DAY CHEMISTRY.

EVERY-DAY CHEMISTRY.

A Familiar Explanation

OF THE

CHEMICAL PRINCIPLES CONNECTED WITH THE
OPERATIONS OF EVERY-DAY LIFE.

BIBLIOTHECA BODLEIANA

BY

ALFRED SIBSON, F.C.S.

AUTHOR OF "AGRICULTURAL CHEMISTRY," ETC., AND ASSISTANT CHEMIST TO
THE ROYAL AGRICULTURAL COLLEGE, CIRENCESTER.

LONDON:
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BIBLIOTHECA·BODLEIANA·

PREFACE.

Works on the present subject are not so numerous as to preclude the hope that another may meet with a successful reception; especially as, at the present time, the majority of thinking persons are more than ever alive to the advantages to be derived from a reasonable application of the teachings of natural science, and especially chemistry, to the practical operations of every-day life.

Amongst the few reliable works on this subject, the chief are Liebig's "Familiar Letters," and Johnstone's "Chemistry of Common Life." No pretensions are made in the present case to compete with the former of these works, which, bearing the name of one of the ablest chemists of the present day, is, undoubtedly, the best of its kind we possess. To this work I am indebted for several of the facts mentioned under Animal Food.

The latter book is also perhaps equally good in its way, especially as an historical and most interesting narrative of the various materials employed by mankind in different parts of the world for their sustenance or their indulgence.

The few discrepancies that may be found between analyses given in the "Chemistry of Common Life" (and some smaller works quoted from it), and some in the

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EVERY-DAY CHEMISTRY.

CHAPTER I.

VEGETABLE FOOD.

THE various commodities embraced under the above title, are, perhaps, on the whole, of less importance than animal food, more especially meat, inasmuch as the latter constitutes in reality the staple food of all but the poorest classes of this country. We give precedence, however, to vegetable food, because we think that the composition of food generally (that is, the nature of its essential constituents, and their arrangement) will be better understood by considering these matters in connection with that kind of produce which is of direct vegetable origin.

In following this arrangement, we can hardly do better than begin with wheat, that is, the grain of wheat,—its meal and flour, as well as bread, and all other forms which this invaluable commodity is made to assume under the hands of the miller, the baker, and the cook. The origin of the grain of wheat, or its formation from the crude materials of the earth, by the agency of vegetable growth, aided by soil and sunshine, air and moisture, does not properly belong to our present subject; we may, however, recall this natural process to memory, as one sufficiently marvellous to excite our highest admiration.

Taking the grain as a starting-point, we may now describe the nature of the materials which compose it, and the connection of these with other kinds of food. Under this head it will also be as well briefly to describe the chemistry of food-constituents generally, and the classification usually adopted to render their several uses intelligible.

The meal yielded by the grain of wheat on grinding consists of the white powder we call flour, interspersed with scaly fragments of the external covering of the grain (the bran), which imparts to the mixture a brownish colour. These two components of the grain are separated by repeated sifting, or "bolting," as the process is technically called. The flour thus obtained is at once fit to be supplied to the baker or to the cook, while the bran is put aside as an inferior material, and used, amongst other purposes, for feeding cattle. As we shall presently show, the entire rejection of the bran is not altogether a wise proceeding, since bran is known to possess nutritive qualities almost equal, and, in some points, even superior to the flour.

A bushel of wheat weighs about 60 lbs., and yields about 47 lbs. of flour and 13 lbs. of bran and pollards.

On kneading up a handful of flour with water, and washing the resulting paste in more water, or better, in a stream running from a tap, we find that the water which flows away is whitened by a substance it takes out from the paste, while a considerable portion remains in the hands as a soft elastic mass, which does not mix with the water, except in the small pieces accidentally carried away.

If we make this experiment on a piece of muslin stretched over the mouth of a capacious vessel, we may collect the whitened matter which runs through the muslin (the object of the muslin is to catch the portions above referred to), and examine the substance thus washed out of the flour. On standing for some hours, this liquid deposits a white sediment (to which its milky appearance was due), which is starch : by carefully pouring off the greater part of the liquid, and transferring the rest, with the sediment, to a plate, or other shallow vessel, and allowing it to dry up spontaneously, we may obtain this material as a white glistening solid.

Starch is an exceedingly curious substance ; it being one of the abundant products of vegetation, and forms a considerable portion of the majority of the vegetable products used for food.

It occurs in all parts of plants; in the grain, or seeds, as in the present instance; in the roots and tubers, as in the potato; in the stems, as in the sago palm, from which sago (consisting mostly of starch) is made; and again, in fruit, as in unripe apples and pears. In nearly every sort of vegetable produce we are about to describe in the following pages, we shall have to mention starch as one of its constituents. In a dry and pure state starch is a granular, glistening solid. Under the microscope it is seen to consist of little clusters of nodules; the shape, size, and arrangement of these varying with each kind of starch; that is, the starch contained in different produce. Thus the starch of wheat, obtained as above, is quite distinct in appearance from that obtained from potatoes, or beans, or sago; so that a mixture of these starches, though homogeneous to the naked eye, may, by the aid of the microscope, be seen to consist of different kinds—a circumstance which assists the detection of adulteration in vegetable mixtures by the microscope.

The above experiment illustrates that starch is insoluble in cold water; that is to say, it enters into no actual mixture with this fluid, as sugar, or any other soluble bodies would.

Starch, though unchanged in cold water, becomes much altered in this fluid on boiling; becoming changed into a thick mucilage, which, on drying in small quantities, becomes rigid and hard like gum; an effect on which its application to the purposes of the laundry depends. This change is due to the starch-cells being ruptured by the heat, and their contents, by absorbing water like a sponge, are greatly increased in bulk; whereby the fluid is thickened.

The better kinds of starch used in this way for imparting stiffness to linen, &c., are prepared from wheat, in a manner analogous to that above described; enormous quantities of the best wheat being used in this manufacture.

The other component of flour, separated from starch in the above-mentioned experiment, is gluten. In order to completely free this substance from the starch, it is necessary to wash and knead it for a considerable time in water; indeed, until the water ceases to be whitened, when the gluten is obtained as an elastic, stringy substance.

Gluten is, perhaps, even a more interesting substance than starch, inasmuch as it is believed to be the most essential constituent of flour; that is, the one on which the nutritive value mainly depends. Gluten is of an entirely different character to starch; its composition being much more complex: it resembles, indeed, in composition, animal food, especially as it consists for the most part of a substance having the closest resemblance to the fibrous tissue of lean meat: this substance is called vegetable fibrine.

Besides starch and gluten, which constitute the greater part of flour, and into which it is readily separated by the treatment above noticed, there are also present in smaller proportions, albumen, sugar, oil, &c., which can only be separated from it by special chemical processes. The following table shows the proportions of gluten and starch, and also the names and proportions of these other components in flour. For the sake of comparison, we also supply the composition of the whole grain of wheat:—

COMPOSITION OF WHEAT FLOUR AND GRAIN OF WHEAT.

	Wheat Flour.	Grain of Wheat.
Water	13·50	15·27
Gluten, with a little albumen	11·46	11·64
Starch, with a little sugar	73·52	68·74
Woody fibre	·68	2·60
Mineral substance	·84	1·75
	100·00	100·00

PROXIMATE PRINCIPLES OF FOOD.

BEFORE proceeding any further, we must inquire more particularly into the nature of starch and gluten; not only because some explanation is necessary to enable us to understand the chemical changes which flour undergoes in the ordinary processes of baking, cooking, &c. (presently to be treated of), but also because these two compounds furnish, perhaps, the best examples that could be chosen of two of the chief classes of food-constituents. Every sort of vegetable food about to be mentioned, we shall find to contain compounds analogous to starch and gluten, which may conveniently be accepted as the types of the groups of food-constituents to which they respectively belong.

Starch and the group of compounds which we have taken it to represent, are distinguished by consisting of three elements, or fundamental constituents. These elements are carbon, hydrogen, and oxygen. The two latter are, in a separate state, gases; that is, aëriform bodies like the air: the former, and more abundant, is a solid when separate; but in its normal state in nature is also a gas (carbonic acid gas). The nature of these elements will be considered more in detail in connection with the subjects with which we conceive they respectively are most associated; for the present, we require to know them only as constituents of starch, and its allied compounds.

The members of the group of food-components now under consideration are, starch, sugar, gum, pectine, mucilage, and cellular tissue. These components of food, all of which will be described in the following pages as we arrive at the commodities in which they severally occur most abundantly, consist of the three elements above mentioned, in some instances with the addition of a small quantity of ash or mineral matter, and in which, also, carbon predominates: hence they are called the carbonaceous group of food-constituents. They are also called the respiratory principles of food, in reference to the important office they fulfil in connection with our internal economy.

We may add, that the elements carbon, hydrogen, and oxygen not only constitute the above group of food-components which predominate in most kinds of vegetable food, and also in a number of other products which, although not strictly belonging to food, are yet in a manner connected with it, inasmuch as they contribute indirectly to its formation by the instrumentality of vegetable growth. Such a substance is cellulose, or woody fibre. This substance forms the framework, so to speak, of all plants, and is sometimes a component, though a useless one as regards nutriment, of certain kinds of food. Linen, cotton, wood, and a number of other invaluable articles of common use, may be classed amongst this group of vegetable compounds.

Again, the three elements above mentioned, in conjunction with another we must now introduce, viz. nitrogen (also a gas like hydrogen and oxygen), not only constitute the greater part of food of every kind (for the next group of food-constituents about to be mentioned also contains them), but also form by far the greater part of all plants, and even animals; in short, of the entire organic world. Hence these elements are called by some chemists the organic elements, and also the organogens, or organic-product-producers.

It must be understood that these terms are only generally true, and correct only in so far as concerns bulk and weight; for several other elements we shall presently have occasion to speak of, though occurring but in small quantities in animal and vegetable products, must yet be considered as essential parts of them.

The curious substance we have become acquainted with under the names of gluten and vegetable fibrine,* is found to differ materially from starch and its allied compounds just named. It differs chiefly by containing a larger number of elements.

Gluten is found to consist of the same elements as starch, *plus* nitrogen, and much smaller quantities of phosphorus and sulphur. Nitrogen has already been mentioned as a gas like the air. As it forms, in fact, the major part of the atmosphere, we shall defer all further mention of this gas until we arrive at that subject. Again, all descriptions of phosphorus and sulphur had best be deferred until we speak of the ash or mineral portion of flour and bread; for the present, we need only regard the presence of these elements as an important mark of distinction between gluten and the other members of its group, and the preceding group represented by starch. Nitrogen being the most characteristic element of this group of compounds, they are sometimes called the nitrogenous principles of food.

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* Although gluten contains small quantities of other substances besides vegetable fibrine, we may, for the sake of assisting the comprehension of our present subject, regard them as identical.

The names of the nitrogenous principles occurring in vegetable produce are, gluten, albumen, and legumine. Gluten is most abundant in the seeds of the cereal plants, as we have seen, and forms one of the chief components of wheat flour; albumen occurs in cabbages and many other garden vegetables; legumine is the characteristic nitrogenous constituent of peas, beans, and other leguminous seeds.

The most remarkable property of these compounds is the great resemblance they bear to the essential principles of animal food. Thus, gluten, as already stated, is much like the fibrine of meat, not only in composition, but also in properties and even nutritive value. Again, the legumine of peas or of beans has the closest resemblance to the cheesy portion, or caseine, of milk: hence, this substance is also called vegetable caseine. We may also add, that albumen from any vegetable produce resembles equally closely the albumen of eggs. Further, gluten, albumen, or legumine, as well as the corresponding substances of animal origin, are also much alike; they all consist of the elements mentioned as composing gluten, and, what is still more remarkable, viz., nearly in the same proportions; hence, they are more closely related to one another than the members of the preceding group. Thus we perceive that gluten and the allied compounds just mentioned, form a well-marked and peculiarly interesting group of food-constituents. They are to be regarded as of a superior character to the foregoing, inasmuch as they are more highly organized, and partake of the nature of animal products. In short, they constitute at once the choicest and highest products of vegetable growth, and the raw materials, so to speak, of animal structures.

It is these compounds only (aided by small quantities of certain mineral salts) which are destined to give us nourishment in the strictest sense of the word, since they are believed to furnish the materials required for building up and strengthening the tissues exhausted by exercise. The non-nitrogenous principles, starch, sugar, &c., cannot do this, although their office is sufficiently important in assisting in the proper disposal of these superior or nitrogenous principles, which are hence called the sanguinous or flesh-forming principles of food. A more elegant name for them, and the one we shall adopt in the following pages, is the plastic principles of food. The functions of both groups of food-constituents above referred to, in relation to ourselves, will be explained in a following chapter.

Gluten, starch, and all other natural compounds occurring in food, are called the *proximate* principles of food; while the elements, carbon, hydrogen, oxygen, &c., of which these principles are composed, are called the *ultimate* constituents of food. The relation of these to one another, and to the composition of food generally, may be understood by comparing the latter to the letters of the alphabet (although the elements or ultimate constituents of all kinds of food are not more than half as many in number as the letters of the alphabet), and the former to words, when the mixture of the proximate principles in the shape of articles of food, as bread, for instance, will hold the relation of sentences and passages of written language. As a few letters will form many words of several meanings, so do the few elements of food give rise to many different compounds of very different degrees of usefulness. Again, as the beauty or the power of a passage of language depends on the choice and arrangement of the words that compose it, so does the wholesomeness of an article of diet depend on the quality and relation one to another of its proximate principles.

This simile becomes still more appropriate if we extend it to vegetable products generally, irrespective of the subject of food; for as in languages we often find the same letters composing words conveying entirely different ideas, so in the vegetable kingdom we find the same elements composing food and poisons.

BREAD-MAKING.

Another property, extending more or less to all the proximate principles of food, is their want of stability, or tendency to change and decay. This is only what we might expect from the complex nature of these substances; for even human productions are, as a rule, the more subject to injury and derangement in proportion to their intricacy or delicacy of workmanship. A similar rule holds good in most cases with respect to chemical combinations. Hence, the essential principles of food, which are probably amongst the most complicated of chemical combinations, can hardly be otherwise than very susceptible to change. At the same time, this tendency is much influenced by the conditions in which these compounds are placed.

Thus, the grain of wheat, containing gluten, starch, sugar, and other fragile vegetable productions, may yet be preserved for a great length of time, if the conditions provided by nature for its preservation be complied with; that is, if we keep it in the ear in places protected from damp. We can even keep it for a considerable time out of the ear, in the shape of grain, if preserved in properly-constructed granaries.

But if we grind the corn, and make it into flour, the conditions for its preservation in perfection are much less favourable, and we cannot long preserve it in this condition without deterioration, even in the best receptacles. It is for this reason that flour is often met with more or less deteriorated. The extent of such deterioration may, however, be imperceptible to the eye, or to ordinary means of criticism, and only becomes apparent from some undesirable quality in the bread or other provisions made of it.

If we mix flour with water, and leave it in a moderately warm place for some days, it will undergo a considerable change; it will have acquired a vinous smell and sweet taste, and also the power of at once imparting to any fresh dough to which it may be added, the chemical change known as fermentation. By the above treatment, the gluten of the flour has undergone a kind of incipient putrefaction, and has converted a portion of the starch into sugar. The further effect of fermentation in the larger quantity, is due to the decomposition of some of the sugar into two new products, viz., alcohol and carbonic acid gas. The nature of this change will be hereafter shown in connection with the subject of BEER.

In a similar manner to the above, leaven is prepared,—the ferment used, from the earliest periods, for the preparation of bread. This ancient method of fermenting bread, though almost, or perhaps quite, extinct in this country, is yet followed to a great extent in many parts of the Continent, the coarser wheat and rye-bread, the "black bread," &c., used by the peasantry, being mostly prepared by this method, which is unsatisfactory chiefly because it generates certain acids and other objectionable products, which impart to the resulting bread a sour and unpalatable taste. We need hardly say, this plan is only followed from necessity, when yeast or "barm" cannot be procured.

In mixing flour with water, yeast, &c., in the ordinary process of bread-making, a similar, but more active change in the components of the flour takes place. Yeast, being a more active ferment than "leaven," effects the above-mentioned change in dough much quicker and more advantageously; whereby the accidental products of fermentation which impart to the bread its disagreeable qualities, may be avoided. The effects of yeast in dough consist, for the most part, in changing a part of its sugar into carbonic acid gas and alcohol, the gradual liberation of the former throughout the substance of the dough, being the immediate cause of the "rising."

On transference to the oven, it is the further endeavour of this gas, and also the alcohol, which from the heat of the oven now becomes a gas, to escape from the stringy and elastic gluten which surrounds them, that distends the dough into a spongy mass, full of small cells and hollows; and by a simultaneous production of gummy matter from the starch, these cavities retain their form and position on cooling, and thus the mixture assumes the characteristic porosity and lightness of bread.

When the dough has been properly kneaded, *i. e.*, when the yeast and other materials have been thoroughly incorporated, the liberation of gas proceeds uniformly throughout the substance of the loaves, and a good light bread results. If, on the contrary, the yeast has not been sufficiently mixed with the other ingredients of the dough, the gases accumulate in large bubbles, which give rise to the large cavities sometimes found in badly-baked loaves, especially in their upper parts. Again, if the heat of the oven has not been sufficient, or too much water has been used in mixing, the walls of the cells or bubbles do not sufficiently harden, and, on the escape of the gases contained in them, they collapse, or, by running together, make "heavy" bread.

The formation of brown crust on the outside of loaves is due to the almost entire expulsion of the moisture, and consequent roasting which this part of the bread is exposed to from the heat of the oven. It thus acquires the crisp character and peculiar taste preferred by many persons to crumb. Crust also contains gum, or dextrine, especially that of "hard-baked" loaves; this being one of the products into which starch is converted by heat. We may remark, by the way, that this conversion of starch into gum in an oven may, with proper care, be conducted so successfully that the product resembles most intimately the gum obtained from natural sources. Large quantities of gum are now manufactured in this manner, which is known in commerce as dextrine, or British gum. For many purposes to which gum is applied, this substance has superseded the more expensive gum-Arabic. The shining surface seen on rolls and some other sorts of bread is sometimes obtained by rubbing over their crust with water, and again returning them for a short time to the oven. By this means, a portion of the gum is dissolved in the water used, and on the evaporation of this, is left as a shiny coating.

The increase in weight of the bread obtained over the flour used is due to a part of the water employed in mixing having become fixed in the bread; the remainder is volatilized during the baking. The average quantity of water in bread, crust and crumb, is 36 per cent.; but this quantity is subject to increase from the manner in which the bread is baked, being greater when many loaves are baked together than when the loaves are baked singly. By a peculiar process, called underbaking, followed by dishonest bakers, it is possible to retain a much larger quantity of water, and so increase the profit. The same end is attained by the admixture of foreign ingredients to the flour, as we shall presently notice. The average composition of good bread is as follows :—

COMPOSITION OF BREAD.

Water	32·5
Gluten and nitrogenous substances . .	8·8
Modified starch, sugar, gum, &c. . .	57·6
Mineral salts	1·1
	100·0

The loss of the characteristic properties of new bread, and the arrival at the condition in which it is usually eaten, or even when it has become quite stale, are changes which do not proceed from the loss of moisture, as we should naturally suppose. New bread does not contain more water than stale; at least, the difference in this respect is quite insufficient to account for the difference in properties, which arises from a molecular change, that is, a change in the position of the particles of the bread. Stale bread may, in fact, be reconverted into new by replacing it, for a short time, in the oven, or by heating it in any similar closed vessel, when it will be found to regain the apparent moisture and elasticity of new bread. What is still more remarkable, this transformation from stale to new bread may be repeated several successive times on the same loaf.

The so-called fancy bread commonly used, is generally made of the best white flour, technically known as "whites;" this is also, in some cases, mixed with milk, sugar, &c.; but the peculiar flavour of this kind of bread depends as much on the manner of baking as upon the ingredients used.

The flour used for ordinary bread is generally of second quality, known as "households," or a mixture of this with "seconds," which is of third quality; that is to say, contains more bran; but, as we shall presently show, this makes a more nutritious kind of bread for general purposes than the best white flour, which is comparatively poor in gluten, although the latter is probably the more digestible.

As is well known, bread is also made of wheat-meal, that is, the natural mixture of flour and bran. This kind of bread, commonly known as brown bread, is undoubtedly a more nutritious food, at least for healthy persons, than the bread made of flour alone; and although but little used in this country, is exclusively eaten on many parts of the Continent, and with the best results. Curiously enough, the little brown bread eaten in this country is, as a rule, consumed by the better classes of society, amongst whom it constitutes a sort of breakfast-table luxury; it is to be regretted, however, that this description of food is not more popular amongst the labouring and poorer classes, with whom bread is often literally the "staff of life." Brown bread is, to say the least, equally nutritious and far more economical, not to speak of the enormous waste of food incurred by the practice of rejecting the bran of wheat as human food.

The bran of wheat, that is, the brown outer covering of the seed, is richer in nutritive elements than the flour itself, although to persons whose digestive functions are not altogether vigorous, these are not always so available as when supplied in flour. On the contrary, this kind of bread often acts in such cases as a gentle aperient,—a property for which it is sometimes resorted to.

Bran is richer in gluten, and especially in the mineral elements of wheat, than flour: its composition has been found by analysis to be as follows:—

COMPOSITION OF BRAN.

Water	12·86
Gluten, "cerealine," &c.	13·80
Starchy compounds	53·20
Oil, &c.	2·50
Woody fibre	11·50
Mineral constituents	6·14
	100·00

In order that we may understand the value of bran, and fully appreciate the value of bread as an article of food, and indeed of food generally, it is necessary that we should know something of its mineral elements; since these, to say the least, are as important as the more abundant components we have so far introduced. We, therefore, now think it advisable to digress slightly from our present subject, in order to make ourselves acquainted with the

MINERAL ELEMENTS OF FOOD.

If wheat, flour, bread, or any other produce, is burned in an open vessel, so that the air may have free access, the greater part of the substance is volatilized as smoke, or as invisible gases, while a small portion is always left, however long the burning may be continued, as a gray or white ash. The great bulk of food which thus disappears on burning, is the starch, gluten, and other proximate principles, which, by this harsh treatment, lose their characteristic properties. This ash must obviously consist of materials derived from the soil where the product grew. As these materials do not form volatile products on heating, they are left after everything combustible is consumed.

This ash is called by chemists the mineral, or inorganic portion of food, and although small in quantity, and therefore, to a superficial observer, insignificant, is, undoubtedly, as important, if not more so, than the more abundant proximate principles we are already acquainted with. The elements of these latter (carbon, hydrogen, &c.) are, probably, only enabled to assume their position, as constituents of food, through the instrumentality of the mineral elements.

But the office of this class of substances does not terminate with the cessation of vegetable life. Their presence is not only necessary to the preparation of food by vegetable growth, but is also necessary to the fulfilment of its office in relation to animal life. Thus, the nutritive value of food, or its adaptation for supporting the health and strength of our bodies, depends very materially on the mineral, non-volatile, or ash-constituents it contains.

We may now enumerate these substances, and briefly narrate their more interesting properties when in a separate or uncombined state. Their uses in relation to our own bodies will be spoken of in a future chapter.

The elements, or fundamental constituents of the mineral portion of food, are,—iron, calcium, magnesium, potassium, sodium; and phosphorus, sulphur, carbon, oxygen, and chlorine. The first five are metals; that is to say, they possess many properties in common with iron, the metallic properties of which are well known, and which may be accepted as the type of this group of elements. Of the second group, the three first are inflammable solids; two of which most of us are well acquainted with, under the names of brimstone and charcoal. The third solid, phosphorus, is not so well known, since it has no common representative. It may be facetiously described as a very excitable brother of sulphur, since it possesses many properties analogous to that body, but is far more inflammable; in fact, is the *most* inflammable substance known. As it burns with great violence and cannot well be extinguished when once lighted, it is a very dangerous material in the hands of persons unacquainted with its properties. Phosphorus and its combinations are, nevertheless, amongst the most, if not *the* most, important elements of food, being most intimately associated with our bodily structure. As we have seen, phosphorus and sulphur also occur in the nitrogenous or plastic principles of food. The two latter elements are gases, like the air; one of them, oxygen, and also the solid above mentioned, carbon, we have seen to be components of the organic or volatile portion of food: they furnish an instance of the truth so prominently taught by chemistry; viz., that the same elements may exist under two or more entirely different aspects. Chlorine is a gas, possessing extremely poisonous qualities. The above characters are only exhibited by the mineral elements of food when in a free or uncombined state; that is, separated from each other to the fullest extent the chemist is able to accomplish: he therefore calls them elements for the time being. But as they occur in food, or even in the soil from which they are derived, few or none of them are separated to this extent.

They mostly occur in couples or in small groups. Thus, the first five, or the metals, never exist in food as metals, but always combined with one of the two latter gases, mostly with oxygen, and are therefore called oxides. Again, the solids, phosphorus, sulphur, and carbon, also occur in soils, for the most part as oxides.

The oxides of the metals form a class of compounds called bases; as lime, for instance, which is the oxide of the metal calcium, corresponding to the oxide of iron, or rust. Again, the oxides of the non-metallic solids (sulphur, phosphorus, and carbon) form a second group of compounds, called acids; as, for instance, sulphuric acid, or oil of vitrol, which is an oxide of sulphur.

Finally, these two latter groups of oxides seldom occur singly, but mostly in pairs, *i. e.*, as salts. Thus sulphuric acid is found in combination with lime, forming sulphate of lime (plaster of Paris). Again, phosphoric acid also combines with lime, forming phosphate of lime (bone-earth). In this latter form, viz. as salts, most of the mineral elements of food are found in the ash of those substances, although they may have formed still more intricate combinations in the food in its natural state.

Thus we may regard the mineral portion of food as consisting, for the most part, of a mixture of salts, the names of which are as follow:—

Oxide of iron.
Phosphate of lime.
Phosphate of magnesia.
Phosphate of potash.
Phosphate of soda.
Carbonate of lime.
Carbonate of soda.
Carbonate of potash.
Sulphate of soda.
Sulphate of potash.
Chloride of sodium.
Chloride of potassium.

A few other substances are less important than the above; such as fluorine, somewhat like chlorine, and silica, or flint. The latter can hardly be considered an essential constituent of food. The mineral substances occurring in wheat, and their quantities are shown in the following table :—

ASH OF GRAIN OF WHEAT.

Potash	29·97
Soda	3·90
Magnesia	12·20
Lime	3·44
Phosphoric acid	46·02
Sulphuric acid	·33
Silica	3·35
Oxide of iron	·79
Chloride of sodium,—a trace	
	100·00

To return to the subject of bread. The facts mentioned in speaking of brown bread also plainly show that the brown and common sorts of flour, which contain most bran, make a more nutritive kind of bread than the best white flour, from which the bran is completely removed.

The popular but mistaken prejudice in favour of white bread, undoubtedly tends to reduce the standard of health in those who partake of it—at least, in the case of persons to whom bread is the staple food, as the poorer classes of large towns. This would be true even if the very white bread were made of the best white flour, but this is well known not to be the case. Coarser or browner flour is still used to a greater or less extent, and the white colour of the bread counterfeited by the admixture of certain substances which have the effect of removing the brown colour : hence further mischief is entailed.

The basis of the foreign mixtures employed for this purpose is commonly alum, the use of which amongst bakers is undoubtedly very common. The habitual reception of this substance in the food must exert an injurious effect, from its well-known astringent nature; but it has been suggested by Liebig that the action of alum is still more injurious in an indirect manner. Phosphoric acid, as above mentioned, is, without doubt, one of the most valuable constituents of flour and bread. Now, this acid forms, with alumina, the basis of alum, a salt which is almost insoluble, and of little or no use in the system: hence the admixture of alum to flour in making bread reduces the quantity of available phosphoric acid.

Alum and other foreign substances are resorted to by unscrupulous bakers, not only to satisfy the prejudice for white bread, but also because, by this means, good flour may be made to retain imperceptibly more water, and hence increase their profit, and inferior, that is, slightly damaged flour, may be made to pass for good.

Alum is not, however, the only substance which exercises this effect upon bread: several other salts act in a similar manner in greater or less degree. The most powerful and the most objectionable is sulphate of copper, or blue vitriol. This abominable adulteration was found some years ago to prevail to an alarming extent in several towns of Belgium. We do not, however, believe the practice is resorted to in this country, for the simple reason that the means of detecting this poison are so simple that it would very soon be found out, and the outcry, and more serious result to the individual using it, that would certainly follow such a discovery, seem to be sufficient to deter unprincipled persons from risking its use.

The only other substances commonly used in this country for adulterating bread, besides alum, as already noticed (which, by the way, is quite bad enough), are common salt in larger quantities than is desirable, potatoes, rice, &c. These latter are, of course, only objectionable on the score of economy.

As most respectable bakers now supply, under the name of home-made bread, a sweet, wholesome kind of bread, baked in separate loaves, and made of ordinary unsophisticated flour, at the same price as ordinary bread, *i.e.*, the so-called "baker's bread," it is difficult to understand why the white, tasteless, and, when a few days' old, hardly eatable stuff commonly found under this name, is preferred.

Poor people have a notion that it "goes further," or is more economical; but a smaller quantity of any better sort of bread is in every way preferable as food.

It is said that an excellent material for improving the quality of bread, or of being substituted for the above-mentioned deleterious ingredients, in cases where flour has become slightly damaged, is lime-water.* This substance is not only perfectly harmless when used in any reasonable quantity, but has been suggested as likely to be beneficial, by increasing the proportion of lime in bread, which is somewhat deficient in this constituent. That the addition of this substance to our food is likely to be advantageous, especially in the case of young children or of persons who eat much bread, is shown by a curious and well-authenticated fact; viz., that in several parts of Germany lime-water is given to young children with the view of correcting the deficiency of this substance in their food, and which is especially requisite at this period of their lives from the important share it takes in the development of bone.

The process of fermentation does not seem to be essential to the preparation of bread, the object gained by its employment arising chiefly from the mechanical effects of the gases it liberates. In some respects it is even an objectionable proceeding, inasmuch as it is not only uncertain, and liable to give rise to bad-flavoured products in the bread, in consequence of the yeast being bad, or from other causes, but entails a considerable loss of the substance of the flour.

Various methods have been proposed, and to some extent adopted, for making bread without fermentation. A recent plan, invented by Dr. Dauglish, certainly promises to supersede the old process; but whether the bread made by this plan is really superior, or as good as when fermented, is still an unsettled question. A passing notice of the more remarkable of these inventions may not, perhaps, be out of place.

An ingenious plan of making bread without yeast is based upon the fact that the common salt added in making bread may be obtained by adding to the dough substances which, by their mutual decomposition, liberate sufficient carbonic acid gas to rise the dough and at the same time form common salt.

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* Lime-water is the clear liquid obtained after shaking up lime with water, and allowing it to settle for some days: a small quantity of the lime remains dissolved in the water, which must be kept in a closed bottle.

Such substances are bicarbonate of soda and hydrochloric acid. By mixing the former with the flour and the latter with the water, we get, when the two are mixed, a decomposition consisting in the expulsion of the carbonic acid of the bicarbonate of soda by the stronger hydrochloric acid; the result being chloride of sodium, or common salt. As this decomposition takes place throughout the substance of the dough, the liberation of gas distends the dough after the manner of yeast, while the resulting salt, for the same reason, becomes uniformly distributed.

This plan, though very complete in theory, is attended with certain drawbacks in practice, which have led to its being now almost disused. The chief objection to the process is the difficulty of obtaining the hydrochloric acid pure, as the acid obtained from common sources is always more or less impure, often containing very deleterious substances.

The plan just alluded to as the invention of Dr. Dauglish, consists in mixing the dough with water impregnated with carbonic acid gas. To make this excellent plan intelligible, we must state that carbonic acid gas is soluble in water, especially when the two are confined together in any close vessel. In bottled beer or champagne a large quantity of this gas is thus dissolved, and remains so while confined in the bottle; but as soon as the cork is removed, some of it escapes as bubbles throughout the liquid.

In this plan of making bread, the flour is mixed and kneaded with water thus saturated with gas, in a suitable closed vessel; on the removal from which, the water begins to liberate carbonic acid, and the dough immediately begins to rise. This ingenious plan of making bread, biscuits, &c., bids fair to be extensively adopted in large bakeries, as it possesses many advantages over the old plan; amongst the rest, a more uniform result, with greater economy, since the constituents of flour lost by fermentation are in this way saved. The process is, however, not likely to become general amongst bakers whose trade is not very extensive, as it involves the use of somewhat expensive apparatus. The process is likewise not altogether free from the imputation of imparting impurities to the bread, &c., made by it, unless care be taken in selecting the materials from which the carbonic acid is generated.

A means much used for imparting the light porous character to articles of confectionery, though seldom applied to bread, consists in adding to the dough solids, which, by the heat of the oven, are converted into gases.

The substance commonly used is carbonate of ammonia, known as "salt of hartshorn." This salt is entirely volatilized by the heat of the oven, and as it is not likely to contain any deleterious impurities, its use in this way seems to be unobjectionable. The same cannot be said of the bicarbonate of soda sometimes used in a similar manner. This salt loses only a part of the carbonic acid contained in it, and the remaining salt is by no means to be recommended as an article of diet.

For the reasons already given, bread must needs be a perishable article of food, its preservation even for a few days being seldom attained without some deterioration, although its behaviour in this respect constitutes, as is well known, the best test of the quality of bread; the better qualities being least affected by keeping any reasonable time.

This tendency to change may be retarded to a great extent by withdrawing the large quantity of water in bread. Thus, if we thoroughly dry bread in thin slices, as in making toast, and keep it in air-tight vessels, it may be preserved for almost any length of time. It is for the same reason that biscuits may be preserved so much longer than bread.

PUDDINGS, PIES, &c.

HAVING now disposed of wheat and flour, as sources of bread, we must briefly advert to the minor applications of the latter, in connection with pies, puddings, and pastry generally.

Preparations of this kind are commonly regarded solely as luxuries, or rather, as palatable adjuncts to more solid food; and this is, no doubt, the correct view as regards the use made of these preparations by the better classes of society. But we are inclined to consider them (puddings more especially) as a more valuable class of food, and worthy of much attention from those who study economical cookery. By this term we understand the art of cooking as modified to suit the purses of poor families and others whose choice of provisions is cramped by *£. s. d.*

Of the more delicate preparations in which flour is more or less disguised with other materials by the efforts of the cook and confectioner, we have little to say, not only because any discussion of this nature would be out of our province, but also because, if we were so to trespass, and to tell the truth concerning the merits of these mixtures as eatables, we should probably get into disgrace, or, at least, be thought despisers of them, which is not the case. We shall, therefore, content ourselves with limiting our observations to the humbler preparations of this character, and to their more utilitarian uses.

We are of opinion that puddings in which flour is the basis, when properly prepared and cooked, may, to a great extent, be substituted, with no disadvantage, for the much more expensive animal food. It is a notorious fact that the art of cooking is, as a rule, but little understood by the poorer and working classes; and hence we cannot be surprised that pies and puddings should be but little known amongst them otherwise than as occasional treats, in which an inordinate quantity of fruit and similar material is generally the chief attraction. But even amongst the better classes, it is seldom we find plain puddings, &c., of so good a quality as it is possible to make them with a little more care and attention in their preparation.

It is only amongst the most intelligent housewives that the art of making good, wholesome, and inexpensive puddings, or, in other words, of making proper use of flour, is understood.*

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* We believe an institution has been lately started in London, under the patronage of a committee of ladies, for teaching women and girls the art of economical cooking (as well as other kinds for domestic servants) at a merely nominal charge.

On boiling in water, flour, when made into a dough, or, we suppose, paste, with water and other materials, undergoes changes somewhat similar to those which take place in the baking of bread. The starch globules break, and form bulky combinations with the water, while, by the same means, the particles of gluten are held apart, and thus lose their tenacious, elastic character. Thus the mass becomes soft and porous, and easily miscible with water.

These changes can only proceed properly at a particular temperature, and completely only when the heat has been long enough continued to allow of these changes taking place in the inner portion of the mass.

The commonest error made in cooking provisions of this kind, consists in not boiling them long enough; in consequence of which, the above changes do not take place, or but incompletely, and there results, instead of the porous or "light" crust above noticed, a bad imitation of it, which is dense, hardly pervious to water, and "heavy." Crust of the former kind is a most nutritive and digestible article of food; it is only the latter kind, and that approaching it, which is indigestible, and deserving of the unfavourable opinion often entertained by many persons of all puddings of this character.

Another practice which we venture to think a mistaken one, is that of using so much suet, butter, and other fatty material, in preparations of this kind. On the exposure to heat in the oven (in the case of pies, to which this passage more particularly applies), the fatty material of course melts, and fills up the cavities opened by the expansion of the starch, while, by a partial decomposition, it gives rise to products very difficult of solution in the stomach. In some cases, we are aware, a large proportion of fatty material is necessary; but, for many purposes, in boiled puddings especially, bread may be substituted with great advantage as regards the production of wholesome food.

While speaking of flour as a component of puddings and pastry, we are naturally reminded of a few other commodities in common use for the same and similar purposes; such as rice, sago, semolina, macaroni, &c.

The two latter materials are prepared from wheat flour of a peculiar kind, by a process we need not describe; and much that we have already said of the nature of flour will apply equally well to these modifications of it.

Rice, although naturally allied to wheat and grain, is very inferior to them as a source of nourishing food, and is at best but a convenient basis for certain kinds of puddings, the active qualities of which are intended to be imparted by some other materials. On this account, and in consideration of its low price, rice is deserving of a place amongst the materials that afford a scope for the exercise of ingenuity in economical cookery; but we must always bear in mind that it ranks very low as a feeding material, and should be used only in conjunction with other more nutritious kinds of food.

Rice, tapioca, and other farinaceous food of this description, are to be ranked with potatoes, since, in common with these useful roots, they consist, for the most part, of farina, or starch; and however useful or palatable they may be, as accessories to other kinds of food, we must not forget that they constitute a class of commodities extremely deficient in gluten or other nitrogenous compounds, and are, therefore, unsuited to form any material portion of the food of persons who undergo much exertion of body or mind. For the same reason, it is an error to give these substances to persons in weak health, with the view of imparting strength; at the same time they are, for the most part, excellently adapted for forming palatable and harmless food for invalids; but other materials, hereafter to be described, are necessary as sources of strength.

The composition of rice will be better understood by reference to the following table:—

COMPOSITION OF RICE.

	Before cooking.	Boiled rice.
Water	14·20	77·02
Gluten	6·40	1·44
Starch	75·70	20·54
Woody fibre	3·01	·80
Ash	·69	·20
	100·00	100·00

COMPOSITION OF OATMEAL AND BARLEY-MEAL.

	Oatmeal.	Barley-meal.
Water	13·09	13·60
Nitrogenous compounds	15·68	11·20
Starch, with a little sugar and oil	68·17	72·88
Woody fibre	1·90	1·30
Mineral salts	1·16	1·02
	100·00	100·00

In the above table we supply an analysis of oatmeal and of barley-meal; not that these substances are to be classified with the preceding, but simply because we think this part of our subject would be incomplete without some notice of them.

Oatmeal is peculiarly rich in the more valuable elements of food, especially in those of mineral origin, and is altogether worthy of a more extended use as human food. It requires, however, a vigorous digestion for its assimilation, and does not seem to be adapted for all constitutions—being most serviceable to persons who lead an active out-door life. As is well known, oatmeal is most extensively consumed in the north of England, where its merits are highly and justly praised, both in the shape of oat-cake and porridge: in the latter form it constitutes an excellent food for healthy children.

Barley is rarely made into solid food, although it yields a bread by no means to be despised in the absence of wheat-bread. As the chief source of beer, it constitutes an article of considerable importance; but all notice of barley in this character, must be deferred till we arrive at "liquid food."

GARDEN VEGETABLES.

Garden vegetables not only contribute much towards the palatability of our dinners, but are, at the same time, a highly useful description of food. What we have instinctively learned of the benefit derived from eating these commodities, along with the usual food which constitutes the staple food of most persons, is in strict accordance with the teaching of modern science, which shows that fresh vegetables contain essential materials, but sparingly present, or altogether absent, in meat.

Thus, for instance, potatoes are admirably adapted for the purpose they are now so universally applied to in this country; viz., as an adjunct to meat. They not only supply an excellent vehicle for taking up the gravy of meat, which, as we shall presently show, is a most valuable portion of it; but from their richness in starch, they dilute, so to speak, the highly nitrogenous compounds of the meat to the proportions best suited for being advantageously disposed of in the system. But the value of potatoes, and especially of green vegetables, as occasional articles of diet, probably depends on small quantities of compounds which have not yet been clearly identified.

Garden vegetables are remarkable for the large proportion of water they contain; even potatoes, which are, perhaps, the most solid amongst them, contain as much as 75 per cent. of water; while in other kinds, as turnips, for instance, the quantity is still greater, being occasionally as much as 92 per cent. A tabular list of the quantities of water present in a few of the common vegetables in a fresh state, may not be uninteresting :—

PROPORTION OF WATER IN GARDEN VEGETABLES IN NATIVE STATE.

Potatoes	75
Cabbage	89½
Turnips	90
Carrots	87
Green peas	80
French beans	90
Lettuce	95
Water-cress	94

The correctness of these remarks may be easily verified by weighing a fresh cabbage-leaf, and after shredding it up, drying it at first near a fire, and finally in an oven, or on a hob until crisp. The extent to which the leaf shrinks, or to which it loses weight, if the trouble be taken to weigh it before and after drying, will probably excite astonishment. This large quantity of water present in vegetables must not be regarded as an encumbrance, or even as of accidental occurrence; it is, in fact, an essential part of the plant itself, and as necessary to its development, as the solids which confer upon it the character of food. Notwithstanding this large quantity of water in green vegetables, they are rich in the mineral elements of food already mentioned, since the small proportion of dry matter they contain is particularly rich in those important compounds, especially in salts of potash. As supplies of these salts are constantly required in our system, we can thus, to some extent, account for the benefit derived from a moderate consumption of fresh vegetables.

The proximate principles of food in garden vegetables are analogous to the gluten and starch of wheat. Thus we find albumen in cabbage, cauliflower, &c., and legumine in peas and beans, corresponding to gluten; while the cellular tissues, gum, sugar, &c., of these vegetables, correspond to starch, although starch itself is not an unfrequent component of these provisions.

As previously remarked, the members of these two groups of food-constituents are respectively much alike in their general efficacy as elements of food; thus, while such vegetables as potatoes, carrots, turnips, &c., consist mainly of starch-like compounds, and are therefore adapted to be used only as adjuncts to more nutritious food; others, like peas, beans, &c., being peculiarly rich in nitrogenous principles of food, are capable of replacing, to some extent, bread and even meat. The eligibility of vegetables in this respect is, however, somewhat qualified by the peculiar properties they possess, which sometimes interfere with their wholesome digestion in the human stomach: hence their value as food differs in different individuals.

We may now proceed to relate the more interesting facts connected with the commoner sorts of cultivated vegetables.

Potatoes have already been mentioned as consisting for the most part of starch; they contain, however, a few other useful materials, the proportions of which will be seen in the following table :—

COMPOSITION OF POTATOES (AVERAGE COMPOSITION).

	In natural state.
Water	75·04
Starch	15·50
Albumen and caseine	2·30
Woody fibre	3·06
Ash	1·06
Gum, sugar, &c.	3·04
	100·00

In a sample of good kidney potatoes, in a cooked state (by boiling without skins), were found :—

77·50 per cent. water
·54 per cent. ash

The other constituents, probably, correspond very nearly to the above.

As the mineral salts of potatoes are amongst their most useful constituents, regard should be had to this circumstance in the manner of cooking them, so as to avoid, as far as possible, loss in this way. If we boil peeled potatoes, a considerable portion of these mineral substances, being soluble, is extracted by the water used, while, at the same time, the starchy products are deteriorated by being partially converted into gum, or other allied soluble compounds,—an effect most apparent in over-boiled potatoes : by these changes, also, the flavour is much reduced. In roasting, baking, or steaming, these defects are avoided, and the quality of the potatoes thereby greatly improved. If potatoes are boiled at all, the skin should be left on till after cooking, as by this means the skin, being comparatively impervious to water, protects the inclosed meal from the above-mentioned deteriorating changes.

Carrots, Parsnips, Beetroot, Turnips, &c.—The first three of these roots have many points in common, sufficient to allow of their being spoken of together, although the third is commonly used in a different manner to the others. They all contain a good deal of sugar. Beetroot, especially, is rich in this substance, and is used on the Continent as a source of this indispensable commodity, the sugar made from it being undistinguishable, when properly prepared, from the best loaf sugar. From this, and other qualities possessed by these roots, we may regard them as useful vegetables. Turnips, probably, rank lowest as regards nutritive qualities amongst the vegetables used as human food ; the large quantity of water they naturally contain, added to the further dilution they undergo in the way they are usually cooked, prevent their being regarded otherwise than as a vegetable capable of imparting a peculiar, and to some persons agreeable, flavour to certain dishes.

COMPOSITION OF CARROTS, TURNIPS, AND PARSNIPS.

	Carrots.	Turnips.	Parsnips.
Water	87·30	90·43	82·20
Albumen, &c.	·66	1·14	1·28
Cellular tissue, sugar, gum, &c., (non-nitrogenous bodies) .	2·56	5·45	8·92
Sugar	5·54	..	3·20
Woody fibre	3·20	2·34	3·47
Mineral matter . . .	·74	·64	·93
	100·00	100·00	100·00

Green Peas, French and other Beans, &c., constitute an exceedingly interesting group of vegetables, and probably rank highest amongst this class of produce.

These plants all belong to the tribe of *Leguminosæ*, or that species of plants which produce pulse in place of grain. While the choice varieties of these plants supply some of the nicest of table vegetables, the coarser varieties both of beans and peas, but especially the clovers, which belong to this group of plants, have an additional interest, inasmuch as they form no inconsiderable portion of the produce raised in agriculture for the maintenance of domestic animals, and, therefore, indirectly administer to our necessities in the shape of mutton and beef. The same may also be said of the group of vegetables last considered, as varieties of those vegetables also form a large portion of the food of cattle which supply us with meat.

In these plants, especially in their seeds, the starch and other carbonaceous principles have much of the same character as in grain, but the nitrogenous principle they contain differs somewhat in its properties from that of grain, although, as before stated, all the members of this group have a remarkable resemblance in their general chemical characters. The nitrogenous principle, which in these seeds corresponds to gluten in grain, is called legumine, or vegetable caseine. This substance is of peculiar interest, inasmuch as it resembles so closely the caseine or curd of milk, as to be considered by some chemists identical. The caseine obtained from each of these source is no doubt chemically identical, as are also most of its properties. The characteristic property of the animal caseine present in milk is that of separation from this liquid under certain circumstances, as curd, which afterwards becomes cheese. The close resemblance of this curd with the vegetable caseine of leguminous plants, is strikingly shown by a fact recently made known, viz., that the Chinese actually prepare a cheese from peas and beans. As legumine is considered almost equally serviceable in the human system as gluten or albumen, we can account for the well-known nutritious qualities of the seeds of these plants as food. Green peas may thus be ranked not only as one of the most delicious garden vegetables, but may also be included amongst the most wholesome and nutritive food.

Again, peas that have been dried (split peas) are a most concentrated food, although not very digestible by weak stomachs. The custom of eating this dish with boiled pork is an excellent and rational one, since the fat pork here dilutes, so to speak, the too-concentrated plastic principles of the peas. Beans, again—that is, French beans, both green and in their pods, as commonly eaten in this country, or dried as "haricots,"—are to be classed amongst the best of food; while the "Windsor," or "broad" bean, although not a fashionable vegetable, is one of the best which our gardens furnish. Lentils, again, so notorious as a component of Oriental dishes, belong to this class of food, and contain even more nutriment than the produce above spoken of; but they possess a peculiar medicinal taste not generally liked in this country. We may add, that lentil-meal forms a considerable proportion of the food known as "Revalenta Arabica."

COMPOSITION OF PEAS AND BEANS.

	In so-called dry state (as used for making pease pudding).	Green Peas (in boiled state).	Beans in dry state as used for haricots.	French Beans (in boiled state).
Water . . .	14·02	84·02	14·20	89·94
Legumine .	23·30	4·34	24·06	2·86
Oil	2·02	·37	1·30	·15
Starch, sugar, &c.	39·50	7·35	37·42	4·36
Cellular tissue	8·14	1·51	10·32	1·20
Woody fibre .	10·42	1·94	9·50	1·12
Mineral salts .	2·60	·47	3·20	·37
	100·00	100·00	100·00	100·00

Cabbage, Cauliflower, Brocoli, &c., although somewhat inferior to the vegetables last mentioned, in point of nutritive value, are nevertheless amongst the most serviceable articles of human diet. The succulent stems and leaves of these plants are rich in salts of potash and other principles, the necessity for which, in our systems, instinctively directs us to make use of such vegetables as a part of our diet: hence the vegetables of this group are peculiarly acceptable to persons who have been compelled for some time to subsist upon dry food. The nitrogenous compound occurring in these plants is chiefly vegetable albumen,—a substance bearing the closest resemblance to animal albumen, or white of egg. Thus we have here another instance of the presence in vegetables of a compound formerly believed to be exclusively of animal origin. This interesting fact, and its connection with the principles of animal nutrition, will be considered in the next chapter, when we come to speak of animal food.

The non-nitrogenous compounds of these vegetables consist, for the most part, of cellular tissue with a little sugar, and smaller quantities of a peculiar oil, which no doubt assists in forming the waterproof surface of the leaves of the cabbage and some other plants of this kind. The "heads" of cauliflower, brocoli, &c., are more rich in food-constituents, especially in the compounds of phosphoric acid, than the leaves; and hence may also be reckoned amongst the best sorts of garden vegetables.

COMPOSITION OF CABBAGE.

	Natural state.	Boiled.
Water	89·40	91·50
Oil	0·10	..
Albumen, &c.	1·50	1·61
Woody fibre	1·14	1·02
Cellular tissue, with a little sugar	7·01	4·09
Mineral substances	0·85	1·78
	100·00	100·00

The larger quantity of mineral matter in this sample of boiled cabbage, was due to the salt added in cooking.

Lettuce, Cress, Onions, &c., although pleasant and useful vegetables, are, on the whole, perhaps less wholesome than those we have so far mentioned, by reason of their being eaten in an uncooked state; in which condition, our stomachs are scarcely adapted to digest even these very tender vegetables. Yet, in the case of salads, these objections are, to some extent, removed by the condiments and oil usually mixed with them, and which correct in a great measure any disturbance the raw vegetables would otherwise be likely to create. Lettuce contains a peculiar principle analogous to the essential principle of opium, and capable of exercising similar effects on some systems, although in a less degree: its action in this respect is sometimes noticed after having eaten rather heartily of this vegetable.

The peculiar pungent smell of onions is due to a very curious sulphurized oil. The well-known penetrating smell of this oil condemns this vegetable to a limited use. It is, however, a wholesome vegetable for persons of strong digestion, and is remarkable for the large quantity of mucilage it contains.

In its general composition it much resembles other vegetables:—

COMPOSITION OF ONIONS.

Moisture	87·684
Albumen, &c.	1·432
Mucilage, &c.	9·770
Woody Fibre	·639
Mineral Matter	·475
	100·000

The well-known perishability and unfitness of green vegetables for keeping, even for a short time after being gathered, are sufficiently accounted for if we recollect the number of complicated organic products in course of development in the structure of the plant, and the large quantity of water surrounding them, which furnishes a most favourable condition for their decomposition when removed from the protection of the organic force inherent in the organs of the plant, and exposed to the attacks of the oxygen of the air. Thus we cannot be surprised that the delicate flavour of freshly-gathered vegetables, the flavour of which depends upon the least stable of these products, should be altogether absent or impaired if the vegetables have been gathered for any length of time before using, or have been packed in large quantities, where they are known to undergo an incipient fermentation. As we might reasonably expect, these deteriorating changes take place the more readily in the choicer sorts of vegetables. Every one must have noticed, for instance, the difference in the flavour of young green peas which have been at once transferred from the garden to the pot, and those which have been brought to market in large quantities, and kept for several hours, or even days.

The cottager who gathers his humble vegetables from his garden as he wants them, enjoys a greater luxury in this respect than the affluent citizen, who, if willing to pay for them, may procure green peas, French beans, or almost any other vegetable, and even strawberries for dessert at Christmas.

FRUITS.

Fruits not only possess many of the substantial qualities of the garden produce last considered, but being, in addition, rich in sugar and peculiar flavouring principles, furnish at the same time some of our choicest luxuries. Fruits are, moreover, highly ornamental, being, next to flowers, perhaps the most beautiful productions of the vegetable kingdom.

Under the above title we include all the common fruits usually eaten in this country, at dessert or otherwise; such as apples, pears, plums, grapes, &c., the general properties of which may be described as follows:—In many respects fruit resembles the common kinds of vegetable produce last mentioned; for instance, they usually contain a great deal of water, often as much as green vegetables; again, we find in them compounds belonging to both groups of food-constituents, although the albuminous, or plastic elements, are generally present only in small quantities, while the carbonaceous principles prevail.

Fruit is thus evidently not intended to form any staple portion of our food, in this climate at least, although some fruits, such as dried raisins, dates, &c., admit of this application under certain circumstances; but from the large quantity of easily digestible sugary compounds they contain in a ripe state, are admirably adapted for the use we instinctively make of them; viz., as pleasant things to eat when we are not hungry.

Fruit in a ripe state essentially consists of sugar, a peculiar vegetable substance called pectine, and water; a little free acid, mineral matter, and minute quantities of essential oils and flavouring principles; the whole supported and held together by cellular tissue, with a little woody fibre. This constitutes the pulp, or the part usually eaten. The seeds or pips of fruit resemble in all essential particulars the seeds of other plants. The core often found inclosing the pips, as in apples, for instance, consists of woody fibre, or simply wood. In stone fruits, the woody character of this protecting envelope to the seeds is strikingly shown.

Many fruits are covered with a rind, often of considerable thickness, as in the orange, and which frequently contains flavouring principles distinct from those in the fruit; thus, the rind of an orange or lemon contains multitudes of oil-globules, which impart the characteristic odour of these fruits. By scratching the surface of these rinds with a lump of loaf-sugar, we may collect the essential oils in the sugar. In the rind of apples we find a good deal of wax, which no doubt performs some useful part (probably of rendering the rind less pervious) in the ripening of the fruit. The general constituents of fruit, such as the sugar, pectine, acids, &c., are much the same in all fruits, the difference in their taste and other qualities being due to the minute quantities of peculiar flavouring principles presently to be described, as well as to differences of structure and arrangement.

The sugar which imparts the sweetness of fruits, differs from the sugar used to sweeten tea, &c., in many particulars. It has a slightly different composition, and is called grape-sugar, or sugar of fruits, to distinguish it from the kind commonly used, which, being prepared for the most part from the sugar-cane, is called cane-sugar. The chief peculiarity of the sugar of fruits is its disinclination to crystallize; hence we commonly meet with it as little granular lumps, as may often be found in raisins. In honey, again, which consists of this kind of sugar, we never find any well-defined crystals, such as may easily be obtained from cane-sugar.

Common, or cane-sugar, ought, perhaps, to be mentioned in this place, since it is closely allied to the sugar of fruits now under notice. Both kinds of sugar resemble starch in chemical composition, and seem to perform a similar office as food. Common, or cane-sugar, seems to be formed from starch in certain plants, especially at a period previous to flowering.

As sugar is a very common vegetable product, and is, moreover, one of the most important commodities of every-day life, a short description of its properties may not, perhaps, be uninteresting.

Although sugar is prepared from the sugar-maple, the sugar-beet, and some other plants, in various parts of the world, the sugar brought to this country is almost exclusively prepared from the sugar-cane, a vast extent of land being devoted to its culture in the West Indies and South America.

White or loaf sugar differs from brown or moist sugar by the absence of those impurities which impart the well-known qualities to the latter kind of sugar, and which consist of products naturally present with the sugar in the juice of the plant. Brown sugar is obtained by pressing the canes between rollers, when the juice which contains the sugar and other substances is extracted. This juice is rapidly evaporated and clarified with lime, which removes a considerable quantity of the foreign matter. The liquid, when sufficiently concentrated, is run into shallow vessels, that the sugar may crystallize. The sugar thus obtained is the raw, brown, or moist sugar, brought to this country in almost incredible quantities for supplying sugar for inferior purposes, and for being converted into white or lump sugar. This latter process is carried forward in large establishments called sugar-refineries. The sugar which does not crystallize is called treacle or molasses.

The refining of sugar consists in the removal of the whole of its impurities, the brown colouring matter especially being the one most desirable to get rid of. The removal of this colouring matter is the most difficult part of the process, and is effected after all mechanical impurities have been removed by straining, &c., by filtering through large bags filled with charcoal made from bones (animal black), this kind of charcoal being at present the only material that can be advantageously used for the purpose.

The colourless solution of sugar is now evaporated in curious vessels called vacuum pans; the object gained by the use of these vessels being the preservation of the liquid in a colourless state, which would be endangered by the comparatively high temperature that would otherwise have to be employed.

When most of the water has been drawn off from the sugar by this means, it is run into conical moulds, where it solidifies, and after all the water has been drained out, becomes lump or loaf sugar.

As this interesting process involves the use of costly apparatus, and requires a large capital, it is chiefly carried on in a few establishments on a very large scale, in some of which prodigious quantities of loaf sugar are manufactured. The beautiful "crystallized" sugar, used for coffee, &c., is prepared in a similar manner.

Pectine is another interesting constituent of fruits. It is sometimes called vegetable jelly, because it resembles in some of its mechanical properties the gelatine of animal origin; that made of calves' feet, for instance. It is this substance which imparts the gelatinous character to the various preserves made of fruit, &c.; as currant jelly, &c. In its chemical characteristics it is related to sugars, and seems to exercise the same functions when comsumed as food.

The acids of fruits next demand attention. In a great many vegetable productions, especially in unripe fruit, and in small quantity also in ripe fruit, we find certain sour substances, which, because they resemble in many respects the acids of mineral chemistry, such as sulphuric acid, nitric acid, &c., have been called organic acids. These acids all differ, however, from mineral acids, by being combustible, that is, they burn away on heating, like any other organic product of vegetable life, and are found to consist of the common organic elements, carbon, hydrogen, and oxygen. The sour taste of unripe fruit, and the peculiar, and, to some persons, agreeable tartness of certain ripe fruits, are owing to the presence of one or more of these curious acids. Thus, in grapes, we find Tartaric Acid, the acid used in effervescing draughts, and to a great extent in certain manufactures. In apples we find Malic acid; in lemons, Citric acid; in currants, gooseberries, &c., a mixture of the foregoing acids. These acids also occur in other parts of the plants than the fruits; for instance, the young stems and tendrils of the vine are rich in tartaric acid, which gives them a sour taste; while in sorrel and rhubarb we find Oxalic acid. This acid is well known as a powerful poison in any quantity; in small quantities it seems to act like the above acids, and seldom exerts any injurious effects when rhubarb is taken in any reasonable quantity, but has been known to do so when recklessly partaken of.

The flavouring principles of fruits constitute an exceedingly interesting group of compounds. They are formed during the latter stages of the ripening of the fruit, from the reaction of the acids above spoken of, with some others then present, upon the sugar also present. These bodies resemble in their nature the fragrant principles of flowers, which consist of volatile oils and ethers; an exceedingly small quantity of them imparting the characteristic fragrance or flavour. An idea of the extremely minute quantity in which these bodies exist in fruits and flowers is shown by the fact of its taking several hundreds of the finest roses to produce a single drop of the precious atta or otto of roses.

Most of these flavouring essences are generated by purely chemical action after all organic growth has ceased; hence there seems no reason why we should not prepare them artificially.

Curiously enough, we have comparatively lately discovered the means of imitating the flavouring principles of many fruits, large quantities of these compounds being now prepared and used by confectioners under the names of "essence of apples," "essence of pears," "essence of pine-apples," &c. We may add, that in a similar manner the scents of certain flowers and other odoriferous substances can be produced artificially; and it is by no means improbable that we may be able, ere long, to prepare in this manner the costly otto of roses, since its composition is nearly identical with India-rubber and with coal-gas.

The most extraordinary circumstance connected with the preparation of these compounds, at least to persons unaccustomed to view things with chemical eyes, is the incongruous nature of the materials from which they are derived; for instance, rotten cheese, rancid butter, gas-tar, and even less agreeable substances, are some of the sources whence these essences are prepared.

A few words about the general chemical changes which take place during the ripening of fruit, may not, perhaps, be uninteresting. During the earlier stages of the growth of fruits, they differ but little in their chemical character from the accompanying leaves, and are found to perform similar functions in the vegetable economy, especially that most important one of absorbing carbonic acid from the atmosphere, and of exhaling free oxygen. At this stage of their development, they consist of little else than woody fibre, cellular tissue, and the ordinary components of leaves; but as their development advances, and they acquire new functions, the chemical changes proceeding in their structure become more complicated, and we find in them starch, and the acids before mentioned, with several other intermediate products. As the process of ripening approaches, these compounds are changed into sugar, pectine, &c., so abundant in ripe fruit. Although it would be needless to trace all the changes which probably take place in the conversion of starch or the vegetable acids into sugar, an idea of the process may be gathered if we say that the products successively generated in the ripening of fruit by the influence of air and sunshine differ from one another but slightly; for the most part only by the elements of water.

The action of fruit as articles of human diet appears to be regulated almost entirely by the condition of the fruit at the time it is taken. Fruit that is perfectly ripe, quite fresh, and free from bruises, &c., may be taken in almost any quantity by healthy persons without producing any ill effects; and even persons in delicate health are frequently able to partake of fruit in this condition with impunity, if not with benefit. On the contrary, fruit that has been kept too long (in the more delicate fruits a few hours is too long), or that has been packed in large quantities, and undergone incipient fermentation, although apparently as good as when recently gathered, has become changed sufficiently to produce all kinds of unpleasant disturbances, especially when eaten with other kinds of food; while fruit which exhibits visible signs of decay from keeping, may almost be called a poison, since it often gives rise to serious complaints.

The fruit hawked about in the summer season in large towns, and consumed by the poorer classes, is often quite unfit to be eaten, and does much harm in this way. The regular prevalence of English cholera, and other complaints of this nature, during the fruit season, are, in many cases, produced, or at least much aggravated, by this cause. In fruits, as in the less delicate vegetable products already noticed, it is the large quantity of water present which renders them so susceptible to decay; hence, if by any means we can get rid of this water by rapid drying at a low temperature, so as to disturb, as little as possible, the natural arrangement of its constituents, we may succeed in imparting a much greater degree of stability to fruit than ordinarily belongs to it. It is in this manner (by drying in the sun) that the delicious dried fruits so attractive in our desserts at particular seasons, are preserved: we need only mention figs, dates, raisins, French plums, &c., as instances. The plums and currants of our Christmas puddings consist of grapes preserved by a similar method, although having undergone somewhat greater alteration from having been packed closely together in large masses. We also meet with apples and pears preserved in a similar manner; but from the larger bulk of these fruits, the preservation of the original flavour is not so complete, although the peculiar flavour of properly stewed pippins and pears is by no means to be despised, even in the presence of more aristocratic fruit.

Certain delicate kinds of fruit, such as strawberries, raspberries, currants, &c., which will not bear preservation by the above means, may be preserved, as is well known, by a skilful admixture with a large quantity of sugar. By thus adding sugar to the natural pulp of the fruit, and diminishing weight for weight the quantity of water, we attain a result similar to what we get by evaporating a portion of the water, as in the above-mentioned drying process.

One of the most interesting properties of sugar is its power, when in a large quantity, to prevent in this manner the decomposition of vegetable products. The preservation of fruits in the before-mentioned processes is also mainly due to this cause.

As the presence of air is another predisposing cause of the decomposition of fruits, we may also prevent their decay by excluding the air from them. It is upon this principle that the bottled fruits are preserved. As this plan is applicable to the preservation of provisions generally, we shall explain it more fully on a future occasion. The following analysis will give an idea of the composition of dried fruits.

COMPOSITION OF DATES.

Water	21·60
Oil	·19
Sugar	56·41
Albuminous compounds	10·93
Woody fibre	2·38
Mineral matter	1·50
Pectine, mucilage, &c.	6·99
	100·00

CHAPTER II.

ANIMAL FOOD.

THE well-known value of animal food, as a part of human diet, is to be attributed partly to the large proportion of nutritive principles it contains, but mainly to the fact of these principles having been modelled, so to speak, into combinations differing but little, as regards composition, from those structures of our bodies which food is tended to nourish: hence but a comparatively slight effort of the digestive functions is sufficient to convert them into available nutriment.

All that we said in the early part of the last chapter, in reference to the three great classes of food-constituents, applies, for the most part, to animal food; since the essential components of this description of food resemble very closely those of vegetable produce. We may, in fact, regard meat as an accumulation of the choicer portions of vegetable food, selected from the large bulk of comparatively useless matter which composes the greater part of the food of the domestic animals reared for furnishing meat. The lean of meat consists, as we shall presently explain, of the choicest nitrogenous principles and the most valuable mineral salts, with small portions of other principles peculiar to animal food of this description.

Although a few kinds of vegetable products are as rich in nutritive elements as meat is, they do not seem to be so serviceable in the human system, probably from the absence of the peculiar animal matters above mentioned.

Animal food being thus more easily assimilated than its equivalent of any vegetable produce, and also, as a rule, more concentrated, it enables us to receive the main supplies of nutriment we require in a compact and convenient form; at the same time affording greater attractions to the palate than are presented by most sorts of vegetable productions.

Animal food is, therefore, admirably adapted for the place it holds, in this country, as the staple food of all who are enabled to procure it. We must not forget, however, that the liberal use of bread and vegetables, in addition to meat, is in no way to be found fault with. On the contrary, such an admixture as we get in our ordinary plain dinners, or perhaps rather, in the ordinary daily meals, is strictly in accordance with the natural rules we are evidently intended to follow in reference to this matter.

Notwithstanding the exceptions we occasionally meet with, of persons who are able to live, and even thrive wholly upon vegetable diet, or, less rarely, with the addition of those milder forms of animal food, such as eggs, cheese, &c., it may be taken as a general rule, that all persons require, as part of their ordinary diet, a quantity of meat proportionate to the amount of labour, either physical or mental, they undergo; since vegetable food of any kind is alone unable to furnish sufficient available nutriment for the maintenance in health of persons actively employed.

It can hardly be doubted that men living upon a vegetable diet, of whatever description, will be unable to compete, in any occupation requiring strength, and especially endurance, with those, *cæteris paribus*, who partake of a reasonable quantity of animal food.

A ¼ lb. of cooked meat (beef) contains as much plastic or strength-giving material as 6½ lbs. of rice, or 4 lbs. of potatoes; and this comparison is made on the assumption that the essential principles of the two kinds of aliment are equally valuable, which is probably not the case; so that a greater difference in favour of meat is perhaps nearer the truth, especially if we bear in mind the greater labour demanded of the digestive functions to deal with the more bulky material.

Thus we can easily credit the stories told of the prodigious quantities of rice consumed by Orientals, or that 10 lbs. of potatoes is no uncommon day's allowance for an Irish peasant.

GENERAL COMPOSITION OF MEAT.

We shall perhaps best make ourselves acquainted with the composition of meat by adopting the common division into fat and lean. The lean is by far the more valuable portion of meat, as, in addition to its being the seat of the albuminous or plastic compounds, and other organic products peculiar to animal food, it also contains the valuable mineral salts of potash, phosphoric acid, &c., which have at least an equal share in imparting the nutritive qualities to meat. The fat is altogether different from the lean, and of a much simpler character. It consists only of a few compounds, which, in reference to food, are to be classed with starch, sugar, and other non-nitrogenous principles: hence they bear the same relation to meat as starch, sugar, &c. compounds do to vegetable food.

To begin with the simpler portion. What we commonly call fat, consists of a mixture of two kinds of fats, called stearine and oleine, and sometimes margarine. Stearine is a hard, solid material, approaching wax in character, and is used, like wax, for making the better sorts of candles. Oleine is a liquid at ordinary temperatures: hence fats which contain much of this substance constitute oils. The characters of the different animal fats are thus, to a great extent, determined by the proportions of stearine or oleine they respectively contain; for instance, suet, which consists almost entirely of stearine, is perhaps the hardest fat furnished by domestic animals; while lard, which is probably the softest from the same source, contains a good deal of oleine. By pressing, this latter may be separated from lard, and furnishes an excellent oil for burning in lamps and for other purposes. In some parts of North America, where lard is abundant, large quantities of this so-called "lard oil" is prepared. Stearine is also easily converted into a fluid by heat. The reason why the fat of meat does not entirely melt off the lean in cooking, is because the fat is inclosed in the membranes and tissues of the animal substance: it is only those portions which escape from these receptacles by pressure or otherwise, that form the dripping in the roasting of meat.

Both stearine and oleine bear some resemblance, although but a faint one, to salts, which, it will be recollected, consist of an acid and a base chemically combined. In these curious fatty substances, we find an acid—stearic or oleic acid—combined with a very interesting compound, which corresponds to the base in mineral salts, called glycerine.

Glycerine, sometimes called sugar of fats, is an oily fluid, having a peculiar faint smell and intensely sweet taste. This singular substance, formerly a curiosity, is now obtained in large quantities in making the composite candles, and has lately been applied to several useful purposes; amongst the rest, as an excellent remedy for chilblains and chapped hands.

The most distinctive feature of the fats of meat is their insolubility in water: however much they may become mixed with the watery juices by melting or otherwise, they always remain as a separate layer, floating on the liquid or gravy. This is the most characteristic property of fats and oils of all descriptions. The above constituents of the fat of meat, with one or two others which we need not care about, all consist of carbon and hydrogen, with a little oxygen.

We may now proceed to speak of the "lean;" but, before doing so, would point out a further distinction between it and the material last considered, viz., that while the proportions and arrangement of the lean are much the same in all joints of the same description, from the obvious reason that it consists of organs essential to the lives of the animals which furnish them; the fat is, for the greater part, an accidental product: hence we find its proportion differing in nearly every joint we meet with.

That which we commonly call lean, or the flesh or muscles of the animal, is, as already hinted, the more valuable portion of meat; indeed it is to this portion of it more especially, that what we have so far said in praise of meat, applies.

The valuable food-constituents present in meat, exist partly as the materials of which the muscular structure is composed,—the fibres, vessels, &c., and partly also as juices, which pervade these vessels and tissues. The substances present in this latter condition are believed to be the more valuable, inasmuch as, being soluble in water, they admit of a more ready appropriation when taken as food.

SOLUBLE PORTION OF MEAT.

If lean meat be chopped fine, and steeped for some time in tepid water, a considerable portion of it will be extracted; and as this portion of meat which is soluble in water, is, as we are about to show, the best part of it, we may regard such water as a solution of meat, *i. e.*, meat in a liquid form. If the watery extract, obtained as above, be gently heated, a flocculent substance soon separates; this is albumen, the substance we are most familiar with as white of eggs. Albumen, in solution, remains fluid at ordinary temperatures; but possesses the singular property of coagulating, or becoming solid at a temperature below that of boiling water: hence it separates from a solution of meat on heating.

Albumen is one of the chief components of meat, not only because of its own value as a constituent of food generally (which is very high), but also because of its usefulness in regard to the more abundant fibrine of meat, in a manner we shall presently point out.

On further heating the solution of meat (after the albumen has been separated by straining) the greater part of the colouring matter separates, and a light brown liquid is left, which still contains much of the valuable materials of meat. In this liquid we find two very curious compounds, called kreatine and kreatinine, discovered, not long ago, by Professor Lieibg, to whom we are all much indebted for the facts he has brought to light on the subject of food. The functions these bodies perform in our systems when taken as food, are not as yet clearly made out; but there is sufficient evidence for believing that they are highly important; indeed, although the quantity of these bodies present in meat is but small, we may fairly reckon them amongst the most valuable of those furnished by animal diet.

In a pure state, these compounds exist as small, white, shining crystals; they are to be classed amongst the most intricate and most potent of organic principles.

In the same liquid there also occur, in small quantities, some other organic principles, the nature of which is at present little known. Amongst these are the savoury principles common to meat generally, as well as those which impart the characteristic taste and smell to the meat furnished by different animals. It is also rich in the mineral elements of meat: these consist of phosphate of potash, chloride of potassium, and other salts already spoken of as occurring in wheat. It is somewhat remarkable that the ash of wheat resembles very closely that of flesh in the nature and general proportions of its constituents:—

GENERAL COMPOSITION OF THE ASH OF FLESH.

Phosphoric acid	36·50
Potash	40·10
Oxide of iron, with magnesia and a little lime	5·60
Sulphuric acid	·97
Chloride of potassium	16·83
	100·00

ESSENCE OF MEAT.

If we evaporate and dry up, in a water-bath or a steamer, the above-described watery extract of meat (after the albumen and colouring matter are removed), we obtain a dark-coloured residue very soluble in water, and having an intensely savoury taste, and which may be regarded as the essence of meat. This obtained, it may be preserved in suitable receptacles, almost any length of time, and may at any time be converted into soup by dissolving in water, and adding salt. It is also applicable as a stock, or basis, in the preparation of other savoury dishes.

This material, prepared as above described, is an exceedingly nutritious article of food, and as a restorative for persons in weak health, as from loss of blood, or during recovery from protracted illness, it is probably unsurpassed by any other restorative agent.

It has been proposed to prepare this essence of meat in large quantities, in districts where meat is of little value. In Australia, South America, and other places where vast numbers of cattle are slaughtered for the sake of their hides and tallow, and where the bones and flesh are actually used, in the latter place, as fuel in the furnaces of the boiler used in the preparation of tallow,—enormous quantities of this valuable substance might be manufactured, which are at present wasted. If properly prepared, it would be an invaluable material in the recovery of convalescent persons in hospitals, or for troops on a march, and for a number of other purposes where a highly nutritive and very portable food is desirable; not to mention the numberless uses it could be applied to in ordinary cookery. It is much to be regretted that an article so precious should be wasted as it is, to a great extent, at the present time.

It is alleged that the neglect to prepare this substance where opportunity offers, is owing to the fact that the small supplies of it that have from time to time been brought forward, have not been favourably received, in consequence, it is affirmed, of the material supplied not bearing out its reputed virtues. The fact is, that the material supplied under the names of "essence of meat," and "portable soup," is too often entirely different in composition to that above described: it is seldom prepared with the necessary care, and is rarely more than a strong jelly, with a little of those flavouring and essential principles of which it ought almost wholly to consist.

GELATINE.

There can be no greater error than to suppose that the jelly of soup, &c., is the most essential portion of it; the contrary is nearer the truth; indeed, it is not too much to say, although we fear it may be received with incredulity, that gelatine, in whatever shape, either as calves-foot jelly, or isinglass, &c., is not only useless as a nourishing material, but actually impedes the functions of nutrition. We do not by any means find fault with jellies of any sort as an agreeable delicacy, because, in the pretty, tremulous condition we usually take them, there is very little else than water or wine about them; the quantity of solid material being exceedingly small; but the idea of partaking of these materials with the view of getting strength, or of recommending them to invalids with the same object, is a fallacy that is rapidly becoming extinct.

INSOLUBLE PORTION OF MEAT.

If the finely-chopped meat that has been steeped in water be pressed out, and this process repeated two or three times, the whole of the soluble matter may be separated, and there is left a white fibrous substance—the fibrine of meat.

This substance when boiled is devoid of flavour, and is, by itself, next to useless as food. Its usefulness in meat, of which it forms the larger portion, depends on the presence of the various soluble compounds already described, especially of albumen. If fibrine is exposed to heat by itself, it shrinks up, and forms a tough, horny mass; but if such exposure take place when it is permeated in all directions by juices containing albumen, as in meat, the contraction of its fibrine into masses is prevented by the interposing solidified albumen. At the same time, its individual fibres, by contracting, become separated, and being held apart by a soft material, the mass becomes "tender" and wholesome as food.

We may now give the results of some general analyses of meat:—

APPROXIMATE COMPOSITION OF COOKED MEAT.

	Beef.	Mutton.	Veal.
Water	40·5	46·0	60
Fibrine, albumen, with a little gelatine	23·9	26·5	29
Fat	34·5	26·0	10
Mineral matter	1·1	1·5	1
	100·0	100·0	100

SINCE, as we have seen, the best part of meat may be extracted by water, it is clear that all unnecessary exposure to the liquid should be avoided, unless the object in view is to prepare soup or broth; in which case the best way of proceeding is to chop the meat fine and let it steep some time in tepid water. By a gentle increase of temperature, the whole of the essential components of the meat are obtained in the liquid.

For this reason, boiling meat is the least economical mode of cooking it; for however careful we may be, a certain loss of useful elements is unavoidable.

The extent to which meat is deteriorated in boiling depends, however, much upon the plan pursued. If the meat is put into cold water before placing it on the fire, the greatest loss of nutritive constituents is incurred, since the juices flow out from all exposed vessels, and are wasted in the surrounding water, while at the same time the water penetrates to a considerable depth into the meat, and by further extraction adds to this loss. The outer layer is thus thoroughly exhausted of everything serviceable, or, as we commonly say, "boiled to a rag," and is next to useless as food.

The economical way of boiling meat seems to be to make the water boil first, then immerse the meat and boil for a few moments, after which the temperature of the whole is to be reduced by the addition of cold water, and the temperature maintained at about 160° Fah. until the meat is judged to be cooked. By this plan the albumen in the outer portions of the meat is at once coagulated, and thus filling up the vessels, prevents the loss of their contents; the greater part of the meat is thus kept separate from the water by a comparatively impervious shell or coating formed in its outer layer.

A similar plan is followed with advantage in roasting. By placing the meat pretty close to a good fire at first, the outer surface retains more effectually the juices of the meat during the subsequent roasting, although in this case their loss from the joint is not of so much consequence, because the gravy is always taken with the meat itself. Roasting is, no doubt, the best method of cooking meat, inasmuch as it not only preserves everything valuable in the meat, but presents them to us in the most inviting condition. During the exposure of the meat at the fire, the juices which exude and become dried up on the surface get exposed to a high temperature, and by a gentle disturbance of their elements give rise to those curious highly-flavoured compounds so attractive to our noses, and still more so to our palates. We need hardly add, that the gravy of roast meat is peculiarly rich in the nutritive elements of meat.

Baking may be considered as a substitute for roasting, although when the operation is conducted in well-constituted ovens in which there is a free supply of air circulating through them, the result is little inferior to that obtained by roasting. In badly-arranged ovens, where no provision exists for the removal of the vapours generated during the baking, these vapours accumulate, and coming in contact with the hot iron, give rise to very unpleasant-smelling emanations, which not only impart a bad flavour to the meat, but render it less wholesome as food.

COOKING.

WHILE speaking of meat and the changes it undergoes on exposure to heat in the different modes employed for preparing it for eating, we are naturally led to glance at the subject of cookery.

The art of cooking is certainly of more importance than we are usually inclined to attribute to it. If its province were only to give palatability to the food we are obliged to consume, it would be sufficiently important; but as, in addition to this, it undoubtedly influences to no small extent the happiness and well-being of mankind, it is certainly worthy of better attention than is usually bestowed upon it. The truth of this latter remark will perhaps be admitted when it is recollected that food is rendered wholesome, or otherwise, almost entirely by cookery, and that the character of food in this respect is certainly connected with our bodily, and even mental health; for, however well able some of us may be, from the possession of a peculiarly vigorous constitution or otherwise, to endure, for a time, without apparent injury, the living upon badly-cooked food, we must, as a rule, inevitably suffer more or less from impaired digestion, if we habitually partake of badly-prepared food; and every one will admit how much our tempers, abilities, and even dispositions are affected by indigestion.

It is rather to be regretted that the art of cooking is too much directed towards making productions agreeable to the taste, without sufficient regard to the objects which food is ordained to fulfil. The skill of the cook is taxed to produce new and luscious dishes to satisfy the often depraved taste of epicures, rather than to devising means of preparing simpler dishes in the best possible condition for human food.

Under the term cookery, we include the entire management of all products supplied to the kitchen for culinary purposes: thus we regard the management of meat, &c., previous to cooking, as well as its selection in a raw state, as important departments of this art, since, as is well known, the quality of meat at table depends as much upon the condition it had acquired by hanging and other treatment, as upon its actual management at the fire. We believe that the quality of meat, and indeed other provisions, as supplied at table, is, within certain limits, entirely under control; that is to say, that the highest possible flavour, combined with the most wholesome condition, may be insured by a reasonable attention to rules founded on carefully-recorded experience.

We must all have tasted standard dishes, called by the same names, and believed to be of the same qualities, but of many different degrees of flavour and other desirable qualities, although no accountable cause for difference existed. In cases of this sort, we must have often wondered why the peculiar richness and general excellence of these dishes in particular instances, does not more frequently belong to them. Although the flavour, &c., of meat are of course influenced by the breed and condition of the animals that furnish it, they depend more on the skill of the cook than is commonly supposed.

We are of opinion that the province of scientific cookery consists in making out the rules upon which the preparation of human food, in the highest degree of excellence, depends; and we believe that food which is most wholesome and most fit to be eaten, will also be the most attractive and palatable to wholesome palates.

Another branch of cookery we have already referred to, viz. economical cookery, is, of course, more limited in its operations than those departments of the subject in which cost of materials is supposed to be lost sight of. Nevertheless, the art of producing the greatest quantity of nutritious and wholesome diet from the cheapest means is a matter of no small importance, especially amongst the less wealthy classes. Considering that the majority of our female population are very ignorant in this matter, and that much unnecessary discomfort, to say the least, is created thereby, it is not too much to say that the promulgation of this art amongst the poorer classes, as a subject of instruction at female schools or otherwise, would be productive of much good.*

DIFFERENT KINDS OF MEAT.

To return to our subject. We have now to inquire into those differences in the flavour, nutritive value, &c., of the meat furnished by the different sorts of animals commonly made use of as human food. The characteristic taste and smell of different sorts of meat are due to chemico-physiological causes, of which very little is at present known; so that none but general distinctions can be noticed.

All kinds of white meat are known to be inferior, in point of nutritive value, to red: this is chiefly because meat of the former kind is deficient in the organic combinations of oxide of iron,—a substance exceedingly important in our bodily economy.

Again, the flesh of young animals is inferior to that supplied by animals which have reached maturity; because, in the former case, the muscular structure is less developed, and the proportions of mineral salts is not so well suited to the requirements of our systems as in the fully-developed animal.

On the other hand, old animals, or those which have been made to undergo much exertion, are even less fit for eating than the preceding, inasmuch as their flesh not only contains much gelatine (a substance we have already deprecated as useless as food), but the muscular fibres have become so consolidated as to resist the loosening effect of the cooking, and the solvent action of our stomachs.

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* See foot-note at p. 22.

The finest and richest meat is furnished by animals of good breed which have been judiciously fed upon the finest of forage, and have undergone no compulsory exertion. Animals of this description were the "fat beeves" of olden times, upon which feudal barons and corpulent friars so well knew how to regale. At the present time, we get this kind of meat most abundantly at Christmas, when the animals that have been fed with all care, for exhibition at agricultural shows, having performed one part of their duty in gladdening the eyes and extending the reputation of agriculturists, afterwards perform a no less important duty in the shape of Christmas beef. In this kind of meat, skilfully roasted, we find all the above-described valuable constituents of meat in the highest perfection.

Although meat cannot be adulterated, in the ordinary sense of the term, it may yet be, and often is, supplied in a condition unfit for human food. The anxiety sometimes felt concerning the possibility of disease being communicated to our system from eating the flesh of diseased animals, is not altogether unfounded; at the same time, there seems to be no foundation for serious apprehension from this source.

It is well known that farmers from all parts of the country reduce the pecuniary loss incurred by the accidental death of their cattle by disease or otherwise, by slaughtering them, if possible, before they actually die from these causes, and disposing of the carcasses at reduced rates. Many butchers, especially those supplying the poorer classes of large towns, are always ready to purchase meat of this description, even although the disease of which the animals died be of a virulent character. It is often difficult to distinguish such meat from that furnished by healthy animals, especially when doctored up by tricks of the trade.

That meat of this character is no worse than that of healthy animals, as sometimes alleged, is too preposterous to merit discussion; that it is not often a direct cause of death, or even of perceptible disturbance of health, is, perhaps, true; but that such meat is at least a possible source of insidious disease, is equally true, and constitutes one of the greatest objections to an indiscriminate animal diet. It is, however, somewhat comforting to know that the human stomach possesses, in a considerable degree, the power of rendering harmless organic poisons. Many compounds which are most virulent poisons when introduced into the blood, are harmless when received into the stomach; so that it is only in rare cases that danger is likely to ensue from an occasional consumption of unwholesome meat.

GAME, POULTRY, FISH, &c.

GAME, poultry, &c., differ but little in their general characters from the animal food already described. The flesh of birds is generally easier of digestion than that of quadrupeds; at the same time it is, with the exception of those included amongst game, as a rule, inferior in nutritive value. Partridges, pheasants, and a few other birds of the kind, probably supply the choicest of animal food, since their flesh combines this easy digestibility with the richest nutritive and flavouring qualities. Birds are endowed with a more rapid, vigorous, and perfect digestive power than belongs to quadrupeds; and hence the flavour and qualities of the flesh of these creatures, at least of those usually converted into human food, is not, as a rule, materially influenced by the nature of their diet. In the rearing of domestic quadrupeds intended to supply our tables, care has to be taken in the choice of the food given to them, to avoid any unpleasant flavour that might otherwise be found in their flesh. There are feeding materials known to agriculturists, the use of which would be highly advantageous were it not for the fact of their imparting a disagreeable flavour to the flesh of the animals fed upon them: hence their use is impracticable. This restriction of food is especially necessary in the case of pigs, as the kind of diet these creatures most relish is by no means calculated to produce well-flavoured pork or bacon. But in the case of poultry, and, indeed, birds generally, so close a connection between the quality of their food and their flesh does not seem to exist. Although these creatures, especially ducks, when left to themselves, partake of a mixed diet, the nature of which we do not always care to investigate, they furnish us, even at a short notice, with a delicate and even savoury kind of meat.

Fish certainly ranks lowest in the scale of animal food, and when cooked in small pieces by boiling, as is frequently the case, in this condition its claim to the title of nutritive food is certainly doubtful. It is not improbable, however, that, amongst other dishes, fish may be beneficial as a source of certain mineral elements generally absent in provisions produced inland.

DIFFERENT MODES OF PRESERVING MEAT.

As meat in a fresh state is extremely perishable, means of preserving it would naturally be sought for. Of these means, the process of salting is that commonly employed, and although attended with considerable disadvantages, yet, in consideration of its convenience and cheapness, it is the only one that can be said to be extensively adopted. Other and superior means of preservation are in use, but being more expensive, and attended by other difficulties, they are employed only to a limited extent.

The chief objection to the process of salting is the serious loss of valuable constituents of the meat incurred by this process. We must all have noticed that in salting meat, a large quantity of liquid or brine is produced; although nothing but salt may have been used, the meat is soon found swimming in brine. This brine is exceedingly rich in the valuable materials of the meat we have before described as being soluble in water: the liquid is, in fact, furnished by the juice of the meat; and although it contains dissolved in it a large quantity of the salt added, which imparts an intensely salt taste, it also contains a quantity of other most precious materials of the meat, sufficient to make its removal therefrom a source of considerable deterioration. It has been recommended to avoid this loss by evaporating the brine until the salt separates, and adding the liquid (which contains all that it is desirable to recover) to the meat when partially cooked, but the inconvenience of doing this stands in the way of its adoption.

The habitual consumption of meat that has undergone this deterioration by salting, gives rise to those lamentable diseases formerly so common amongst seamen and other persons who are deprived for long periods of fresh provisions. The injury in these cases arises, not so much, as is often supposed, from the presence of too much salt, but from there being too little of the soluble salts of the meat, on the presence of which, as we are already aware, its value so much depends. These deficiencies of salt meat can to some extent be corrected by green vegetables, which are rich in potash and other mineral elements; hence the evil effects of a salt diet are soonest apparent in cases where these useful articles of food are wanting.

In the process of smoking meat, the most active agent is a curious empyreumatic substance called creosote. This compound is always generated where wood and turf are burned, and is the cause of the irritating effect of this kind of smoke on the eyes. Creosote is an exceedingly powerful antiseptic, a very small quantity being sufficient to retard decay in organic matter. For this reason it is largely employed by engineers as a means of preserving soft timber from decay when exposed to the weather or to damp earth. Creosote exerts a similar effect on animal substances; and a very small quantity, such as occurs in wood-smoke, is sufficient to produce an antiseptic effect on any animal matter exposed to it; while, at the same time, it imparts, with other empyreumatic compounds also present in smoke, the peculiar flavour of smoked provisions which some persons esteem.

The best mode of preserving meat, and, indeed, vegetables and provisions generally, seems to be by a process not long ago made known by the distinguished philosopher Gay-Lussac. The process is now frequently employed on a small scale by private individuals, as well as extensively in large establishments; it having given rise to a new branch of trade, which is rapidly extending. The operation consists essentially in packing up the material to be preserved in canisters or in bottles, which are hermetically sealed. The whole is next gradually raised, with proper precaution, to the temperature of boiling water, and this temperature maintained until the inclosed substances are judged to be cooked, when the heat is withdrawn.

It is found that meat that has undergone this treatment, will keep for almost any length of time, provided the exclusion of the air is perfect; so that even after the lapse of several years the provisions are found, on opening the canister, in as good a condition as when inclosed. The operation depends upon the fact that all organic substances, by exposure to the temperature of boiling water, lose their property of fermenting and decaying, provided the subsequent access of air is prevented. The disagreeable flavour and putridity, generated in meat by keeping, are consequences of the action of the oxygen of the air upon the albuminous compounds of the meat: hence, if we exclude the access of oxygen, by placing the meat in a closed receptacle, and now absorb the small quantity of oxygen inclosed with the meat, by exposure to a boiling heat, all further change is arrested. The superiority of this process lies in the fact that none of the constituents of the meat are lost; it therefore retains its nourishing and palatable qualities, while any waste from the formation of useless materials is prevented.

It is obvious that this mode of preserving food must possess many advantages in the victualling of ships, fortresses, armies, &c., and in all cases where a complete means of preserving provisions for indefinite periods is highly desirable. It has, however, one disadvantage; viz., as we cannot see and examine what we purchase, we are obliged to rely on the word of the manufacturer for the good quality of the goods received: hence, if we happen to deal with dishonest persons, we may find, on opening our canisters, treasures altogether different to what we bargained for. It may, however, be truly said that this source of disappointment may be avoided by examining a few samples, taken at random from amongst a number of packages; but if, as it sometimes unfortunately happens, the examination is carelessly performed, a dishonest dealer may succeed in disposing of worthless goods, and create more serious mischief by deceiving those to whom the goods are sent, as to the quantity of available food at their command. It will be remembered that complaints of this kind reached us from our army in the Crimea during the late war, and much commotion was thereby caused about these preserved provisions.

Notwithstanding these disadvantages, this process is an excellent one, and with proper management is certainly the best means we possess for protecting ourselves from the evils likely to arise from an irregular supply of fresh provisions.

DAIRY PRODUCE.

Having now disposed of animal food, usually so called, we have next to treat of the milder kinds of food of animal origin; viz., milk, butter, cheese, eggs, &c.,—commodities which form a no inconsiderable proportion of human diet.

MILK.

Beginning with milk;—we might fairly expect that milk would be exceedingly rich in nourishing materials, since it is the food first tasted by all ranks of mammalian animals, and the food upon which they make most progress in the shortest time. The constituents of milk are much the same in all species of mammalian animals, the difference in the qualities of milk depending on slight differences in the proportions of the constituents. As cow's milk is that almost exclusively employed in this country for the preparation of dairy produce, the following remarks apply more particularly to this kind of milk. We shall better understand these remarks by first observing the general composition of milk, which may be represented as follows :—

COMPOSITION OF MILK.

	Cow's milk.	Ass's Milk.	Human Milk.	Cream.
Water . . .	87·04	91·65	88·80	62·50
Caseine . . .	4·26	1·80	3·82	5·62
Butter . . .	3·13	1·12	3·04	30·58
Sugar . . .	4·77	5·03	4·20	trace
Mineral constituents	·80	·40	·14	1·30
	100·00	100·00	100·00	100·00

It is the fat or butter of milk that imparts its characteristic white, opaque appearance. The fat occurs in a multitude of little globules, which, distributed throughout the substance of the fluid, give rise to its peculiar white colour. The fat gloubles being slightly lighter than the fluid in which they float, slowly rise to the surface on standing, and form a layer, more or less thick, which we call the cream. By suitable means the whole of the fat globules can be removed, and a transparent liquid obtained, which contains all the other constituents of the milk.

It is often supposed that the cream is the essential part of the milk, and we hear of its being given to children in the belief that it is a kind of concentrated milk of superior nutritive value. This, however, is not the case; cream is only rich in fatty substances, and its use in our system is much the same as is performed by the fat of meat. Indeed, we may say that cream or the butter is to milk, what fat is to meat;—viz., that portion which furnishes respiratory material. We may, however, regard it as a superior and more highly organized kind of fat; since it approaches more nearly to the kind of fat occurring in our own bodies.

The market prices of new and skim milk are quite disproportionate to the relative nutritive value; since the latter, having lost nothing but its cream (a material for which other substances could be easily substituted), is but little inferior, in point of feeding qualities, to new milk; and where, as in many country districts, skim milk of better quality than that frequently supplied in towns as new, can be had for a halfpenny a quart, a more extended use of it amongst poor persons would be greatly to their advantage.

In milk from which the cream has been removed, the other constituents may be separated as follows :—On the addition of a few drops of hydrochloric acid, or of vinegar, the caseine, or cheesy matter, separates in flocculent masses. When this is removed by straining, we have left in solution, the sugar and the greater part of the mineral salts, which may be obtained by evaporating, or boiling off the liquid in a water-bath until it dries up. The caseine is, perhaps, the most interesting of the above-named constituents of milk. Caseine is one of the group of plastic elements already spoken of as the flesh-forming materials of food. It resembles very closely, in its chemical properties, the gluten of grain, or the fibrine of flesh. We have also mentioned the close relation that exists between the caseine of milk and the vegetable caseine of peas, beans, and other leguminous products. The mineral elements of milk are exceedingly rich in phosphoric acid, a substance especially necessary in the development of the bones of the young animal it is intended to feed, with the other salts of food.

The sugar of milk, to which its sweet taste is due, is of a different kind to that of fruits, or of the sugarcane, before noticed. It is much less sweet than either of these, and in a separate state tastes gritty in the mouth, from its being less soluble. It might be prepared in large quantities from whey, if any considerable demand for it existed. At present, it is used only occasionally in medicine, and chiefly as the basis of homœopathic globules, and a few other purposes.

The value of the above-named components of milk is much enhanced by their being proportioned by the hand of Nature to the wants of the young animal for which it is provided. Moreover, these components resemble very closely the materials required to build up the organs of the young animal; so that a comparatively simple change, such as can be accomplished by its yet feeble digestion, is sufficient to convert them into available aliment. For these reasons the full value of milk is only appreciated by very young creatures, whose organization is adapted for its reception; and hence milk is not proportionately so serviceable to adults.

Where milk forms any considerable article of diet (as when employed in the preparation of oatmeal porridge, and especially as food for infants), especial care should be taken to insure it being pure milk, *i. e.*, milk yielded by *cows*, and by cows which live in a healthy condition. Attention to this matter is especially requisite in London and other large towns, where the white fluid supplied under the name of milk, is often yielded by pumps, and bears but a very remote connection with this fluid.

Even charitably supposing that the adulteration of milk consists only in the addition of water to it, although stories are told of much less objectionable adulterations being employed, a great deal of the milk supplied in the above localities is altogether unfit to be used as a part of the food of young persons, for the reason that it is yielded by cows in a more or less diseased condition. It is notorious that the cows of small milk-sellers are frequently kept in cellars situate in close neighbourhoods, and fed only in the manner calculated to get from them the greatest quantity of milk, altogether regardless of quality. It scarcely needs chemical or physiological evidence to persuade us that the milk obtained in this way is utterly unlike the secretion above described, which is only yielded by healthy animals. We believe there are to be found in London respectable agents, who really are supplied with proper milk from the country; and we would strongly urge the propriety of procuring the milk required for domestic purposes from these or other wholesome sources.

BUTTER.

BUTTER, as we are all aware, is the fatty matter obtained from cream and from milk by churning. The minute white globules above spoken of as giving rise to the characteristic opaque appearance of milk, consist of little bags or bladders of membrane inclosing the fatty materials, or butter.

Butter, in a fresh state, like the fat of meat already described, consists of two or three kinds of fat, besides two or three volatile compounds in minute quantity, which impart the much-esteemed smell and taste. Butter has the following composition :—

Water	7·0
Caseine	5·0
Mineral substances	0·8
Real butter	87·2
	100·0

By violent agitation, as in churning, these globules are broken, and the liberated butter collects together in masses. A similar result is obtained by heating the cream, and butter is prepared by this mode at several places on the continent.

The fats present in butter are chiefly margarine, oleine, with small quantities of butyrine. While butter consists for the most part of the fatty matter of milk, it also contains smaller and variable quantities of all the other constituents of the milk; and although these, being regarded as impurities, are got rid of as much as possible by skilful washing and kneading, yet it is scarcely possible to obtain the butter wholly free from these admixtures. It is these foreign substances left with the butter which impart its tendency to spoil and become rancid: hence, the more carefully the butter is freed from them, the better it is likely to keep. It is the caseine or cheesy matter especially which is most liable to undergo change, and communicate its disturbing influence to the fatty acids of the butter, and by a simple transformation changes the butyric acid (the most characteristic constituent of fresh butter) into capric or caproic acids, and other compounds peculiar to rancid butter.

By repeated boiling with water pure butter may be obtained, as by this operation the whole of the impurities of ordinary butter are removed. Rancid butter may even be purified and made palatable by these means. The butter procured in this way is, however, very inferior in flavour to that recently churned.

The effect of salting butter is chiefly to prevent the caseine entering into putrefaction. The salt preserves it, as it does salted meat; but in order that the salt may perform this office, it is necessary it should come in contact with every particle of the cheesy matter distributed through the butter: hence much skill is requisite to perform the operation of salting butter successfully.

CHEESE.

Cheese undoubtedly merits the first rank amongst dairy produce, both on account of the time, skill, and labour involved in its production, as well as from the fact of it being one of the most useful articles of food. Cheese that is properly ripe and well-flavoured is certainly one of the most agreeable and nutritious kinds of food; it is also a very concentrated food, so that we consume it with most benefit in small quantities and in company with a comparatively poor food like bread. The time-honoured refreshment of bread and cheese, to which, when of the best possible quality, few eatables are superior, affords an instance of the instinctive discovery of an admirable mixture of food.

The value of cheese as a source of nutriment depends almost entirely on its age and condition; while poor horny cheese is probably the most worthless rubbish called by the name of food, because so thoroughly indigestible, that of good flavour and in mellow condition is exceedingly wholesome, at least for most persons; and that it aids the assimilation of other kinds of food, the popular custom of taking cheese at the conclusion of dinner would seem to show. Cheese that is in a state of incipient decay, or rather putrefaction, is most effective in this respect; and the agreeable stimulative action of this kind of cheese is probably in part due to the small quantity of ammonia it gives off. The smell of ammonia, or hartshorn, amongst the peculiar odours from old cheese, may often be noticed. Ammonia is formed in these cases from the nitrogen of the cheese being liberated by decay from its organic combinations, under which circumstances it always passes off as ammonia.

The most essential constituent of new cheese is the caseine of milk, although in the better sorts of cheese a great deal of butter is also present. These, the principal original constituents of cheese, by keeping, under certain circumstances undergo more or less change, the nature of which is in a great measure dependent on the treatment pursued in the preparation of the cheese. Very slight differences in the mode of management are found to influence the quality of the cheese produced; and still greater causes of variation are ascribed to the character of the soil of the district in which the manufacture is carried on, or rather of the vegetable produce on which the cows have been fed.

We have already sufficiently described caseine and its connection with the other plastic elements of food.

Caseine being insoluble in watery fluids, is kept in solution in milk by the intervention of an alkali,—soda. The small quantity of free alkali present in milk is believed to keep the caseine in a fluid state; but if by any means this alkali is neutralized or overcome by any of its antagonists, the acids, separation of the caseine ensues. We may satisfy ourselves of this by adding to milk a few drops of any acid, when the cheesy matter will quickly separate.

A similar effect takes place when milk is exposed to air. The "turning sour" of milk is caused by the formation of an acid from elements already present in the milk. The sugar of milk referred to becomes, by a very slight derangement, changed into an acid called acid of milk, or lactic acid, and this neutralizes the soda and precipitates the caseine, just as if an acid had been added.

The curdling of milk on a large scale for the preparation of cheese, by means of rennet, is probably due to the same cause. The rennet acts as a ferment on the sugar, and rapidly converts some of it into lactic acid, which effects the curdling: hence we are able to account for the efficiency of the minute quantity of rennet employed in the operation. If the separated caseine or curd is not removed from the whey, and the latter thoroughly pressed out, acid continues to be formed, which interferes with the quality of the cheese: hence, a complete removal of the whey from the new cheese is a point of much importance in its preparation.

The quality of cheese depends much upon the amount of cream left with or added to the milk. The larger the quantity of cream present, the richer the cheese will be; but at the same time it becomes proportionately less able to bear keeping. Thus, in the rich cream-cheese there occurs only a small proportion of caseine, and consequently it cannot be preserved longer than a few days; while in the poor so-called skim cheese there is little else than caseine; and, consequently, it will keep for any length of time. Again, in Stilton cheese, in the preparation of which cream is added to the natural milk, we have an exceedingly rich cheese, but very subject to decay.

Double-Glo'ster, Cheshire, and Chedder, and other good ordinary kinds of cheese, are usually made from the natural milk, that is to say, with the natural proportions of caseine and butter. During the ripening of cheese, the fatty elements of the cream react upon the moist caseine, which becomes more or less altered from its original condition of curd, and assumes the peculiar properties of cheese. At the same time, certain flavouring principles are generated from the glycerine present in the cream, which imparts the pungent agreeable taste and characteristic odour. In order that these changes may proceed satisfactorily, it is essential that the ripening process shall proceed in rooms of a low and even temperature. This seems to be one of the chief points to be carefully attended to in the management of cheese.

GENERAL COMPOSITION OF CHEESE.

	Chedder.	Double Glo'ster.	Skim.
Water . .	36·64	35·61	43·64
Caseine . .	23·38	21·76	45·64
Fatty matter .	35·44	38·16	5·76
Mineral matter .	4·54	4·47	4·96
	100·00	100·00	100·00

The peculiar flavour of the cheese made in different districts depends more upon the system pursued in its preparation and its subsequent management than upon the peculiarities of soil and climate, although these circumstances, with others less direct, undoubtedly influence to some extent the quality of the cheese produced.

It is said that a peculiar flavour may be imparted to cheese by inoculation; but any transmission of flavour effected in cheese by the insertion of a piece of another sort, can of course only take place between two sorts that are otherwise of equal quality.

A curious circumstance connected with cheese is the popular prejudice in favour of colour. While cheesemakers admit that the addition of colouring matter serves no purpose but to satisfy the popular liking for it, and consumers are mostly aware of this, the silly custom still remains amongst those that we have yet to grow out of. Although the drug commonly employed for the purpose, viz., annatto, is usually quite harmless in the quantities received in cheese, yet, as the drug is a powerful purgative, a larger quantity, such as may be taken in highly-coloured cheese, is not uncommonly followed by inconvenience.

EGGS.

While speaking of dairy produce, we are naturally reminded of eggs, although these articles have but a customary connection with the foregoing commodities.

Eggs are peculiarly rich in albumen; hence, they are to be classed amongst the most nutritive kind of food. The value of eggs is, however, much influenced by the manner of cooking them; if boiled too long, and rendered hard, their value as food is much diminished. They are most useful when lightly boiled, and eaten with other weaker kinds of food; so that the custom of eating eggs with bread and butter at breakfast is quite in accordance with the teachings of science. Again, the custom of eating eggs with ham or bacon is, for the same reason, an excellent one.

The yolk of eggs differs from the white only by the presence of yellow oil-globules. The shells of eggs consist almost entirely of carbonate of lime, which, being very soluble in acid, may be completely removed from eggs by immersing them in dilute hydrochloric acid.

COMPOSITION OF THE EGG.

Water	74·02
Albumen	14·08
Oil and fat	10·25
Mineral constituents	1·65
	100·00

CHAPTER III.

LIQUID FOOD.

UNDER the above title, we propose to speak of the various beverages in common use. These may conveniently be considered under the heads of Fermented Drinks, including beer, wine, &c., and Non-fermented Drinks, such as tea, coffee, and a few other less commonly used liquids. To begin with

BEER.

CONSIDERING the great popularity of beer, and the large quantities of it consumed amongst all ranks of persons in this country, we may almost assign it a position amongst beverages corresponding to that held by bread amongst solid food. Although we are perfectly aware that beer does not possess so fair a claim to the title of food as bread does, yet it must be ranked amongst the useful, and certainly amongst the most palatable, commodities at our disposal.

We ought first, perhaps, to give an outline of the process of brewing generally, so that we may point out the more interesting chemical changes connected therewith. We may then glance at the peculiarities of different sorts of beer, and the general causes thereof.

As every one is aware, the principal material concerned in the production of beer is malt, which may be regarded as barley that has undergone a very curious chemical change. This change consists, for the most part, in the conversion of starch into sugar. We may regard this change as a species of fermentation, inasmuch as it is effected by an agent which determines the disruption of the atoms of starch, and their rearrangement in the form of sugar,—a change which appears the less surprising if we recollect that these two substances are much alike in chemical composition. The agent which effects this change is sometimes called diastase, but which may be regarded as the nitrogenous compounds of the grain in an incipient state of decay.

When grain is exposed to a gentle heat and moisture, the gluten it contains is, in a short time, converted into diastase, which quickly converts the starch into sugar. This change proceeds simultaneously with the germination of the grain or seed when placed in the earth, and is evidently provided by nature to supply nourishment to the young plant. That the change of starch into sugar is, however, a chemical process, independent of the germination of the seed, is proved by the fact that sprouted grain, or merely a watery infusion of it, added to fresh starch, will soon convert the latter into sugar.

Warmth and moisture are the only conditions necessary for the germination of grain, which may even take place in the ear as soon as ripe. This is, in fact, the chief danger dreaded by farmers in wet harvests, as by a prolonged rain at this season, entire crops may be spoiled in this manner.

The process of malting essentially consists in inducing an artificial germination in the grain, by moistening it in heaps kept at a rather warm temperature. By this means a considerable portion of the grain becomes soluble in water, from the action of the above agent. The second part of the process consists in arresting the further progress of the natural process of germination, by baking or drying in malt-kilns, whereby the sugar is preserved that would otherwise be disposed of in ministering to the early development of the young plant. The principal object gained by malting is thus to obtain an economical source of sugar, this substance being the chief constituent of malt, although others take a minor part in determining the character of the beer made from it.

It need hardly be said that the grain used in this country for making malt is barley; most of the barley grown in this country being applied to this purpose, for which it is well suited in consequence of the large proportion of starch, and comparatively small quantity of nitrogenous matter it contains.

The brewer proceeds to make malt into beer, by extracting it with water in the process of mashing, which consists in adding successive quantities of hot water to the crushed malt, by which the latter is deprived of its sugar, and the smaller quantity of other soluble materials it contains. The first quantity of water added, of course takes up the greater portion of the soluble materials from the malt, and is used for strong beer, while the second or third quantities of water added are either used for making reduced strengths of beer, or are added to fresh quantities of malt, instead of raw water. The malt having by this means been completely exhausted of everything soluble in water, is now called grains, and as it still contains a considerable portion of nutritive principles of the barley, is an excellent food for cattle,—a purpose to which most of the malt, after extraction, is applied.

The extract of malt obtained as above, now called the "wort," is next boiled with hops. Before proceeding further, however, in describing the process of brewing, it will be well to bestow a few words upon the second component of beer.

The external character of the hop-plant is known to almost every one who has ever had anything to do with a garden, as its beautiful foliage, and many useful habits as a climbing-plant, make it a common favourite. But, although the hop grows readily in almost any garden, it will bear flowers of good quality only when cultivated with every care, in the best of soil: hence the best part of the "Garden of England," as the beautiful county of

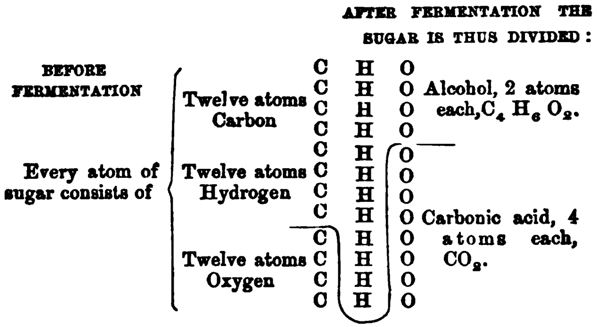
Kent is sometimes called, and a few other fertile spots, are set apart for the cultivation of this plant, demanded so extensively in making beer. Even under these circumstances, however, the yield of hops is so extremely precarious, owing to the development of the plant being subject to many casualties, as blight, &c., as to render its cultivation a great speculation.

As the hop-flowers, like nearly all organic produce, contain, in their fresh state, a large proportion of water, they have to be dried in a kiln, as soon as gathered, in order to preserve them. The hops are thus supplied to the brewers in a nearly dry state.

The essential portion of hops constitutes but a very small proportion of their bulk and weight. The bitter principle is, of course, their most important constituent: the nature of this substance has not, however, as yet, been properly studied. Its effect on the human system is unquestionably beneficial, in the quantities occurring in beer. The bitter principle of hops is thus one of the most useful constituents of beer. There also occurs in hops an essential oil, which, being slightly volatile, helps to impart the characteristic odour of good beer.

The quality of the hops employed, greatly influences the character of the beer; hence the selection of good hops is a matter of much importance in breweries where the more refined kinds of beer are made. The infusion of malt having been boiled with the requisite amount of hops, is next rapidly cooled, and passed into large vessels to ferment. The fermentation of beer is an exceedingly curious process: it is always set going by means of yeast or barm. Yeast is now known to be a plant of very low organization, which rapidly grows at the expense of the materials present in the beer. At the same time, it determines the separation of the sugar into alcohol and carbonic acid. The small quantity of yeast added, rapidly spreads throughout the liquid, setting up, as it goes, the commotion known as the alcoholic fermentation. After this process, a part of the yeast floats on the surface of the liquid, while some falls as a sediment to the bottom, forming the so-called "bottom yeast."

This transformation will, perhaps, be understood by reference to the following diagram. We must imagine the group of elements constituting sugar, to separate themselves in the manner shown by the line drawn through them, into alcohol and carbonic acid :—


AFTER FERMENTATION THE SUGAR IS THUS DIVIDED :
BEFORE FERMENTATION
Every atom of sugar consists of
Twelve atoms Carbon
Twelve atoms Hydrogen
Twelve atoms Oxygen
C H O
C H O
C H O
C H O
C H O
C H O
C H O
C H O
C H O
C H O
C H O
C H O
Alcohol, 2 atoms each, C4 H6 O2.
Carbonic acid, 4 atoms each, CO2.

This kind of fermentation is common to all the beverages of the class we are now speaking of, and by it they acquire that peculiar property which they all possess in common, though in different degrees, viz., that of intoxicating when taken in undue quantities. This property is owing to the presence of alcohol, the production of which is the most characteristic result of the above kind of fermentation. The consideration of the effects of this body on the human system must be deferred till a future chapter, in which we intend to trace the purposes performed by the different kinds of food. For the present, we need only remark that in a separate state, alcohol is highly injurious; but when much diluted, is usually classed amongst the respiratory principles of food.

The chemical properties of alcohol are as follows :—In a pure state, it is a transparent, volatile liquid, lighter than water, and having a peculiar and pleasant smell. In consequence of its great attraction for water, it is extremely difficult to separate it completely from this liquid, and when separated (known to chemists as absolute alcohol), can only be preserved in a pure state in carefully-stopped bottles : its avidity for water is so great, that it absorbs this liquid from the air on exposure. Alcohol is very inflammable, even when mixed with much water; hence spirits of wine, which consists of about eighty-five parts alcohol and fifteen water, is much prized for burning in lamps, notwithstanding its high price, when a perfectly clean flame of great heat is desired.

The other product of this transformation, viz., carbonic acid, is a heavy invisible gas, which will again be more fully spoken of in connection with aërial food. During the fermentation of beer, wines, &c., large quantities of this gas are generated from the sugar, as shown in the above plan of the process; from which we perceive that every atom of sugar changed by fermentation, gives rise to four atoms of this gas, besides two atoms of alcohol. It is this gas, in escaping through the liquid and meeting with glutinous impediments, which gives rise to the frothing up of liquids of this kind during fermentation. It is also the cause of the peculiar sensation experienced on holding our faces over the tubs in which the fermentation is proceeding.

The whole of the sugar is not removed from beer by fermentation, as we might suppose; a small proportion is always left, and forms one of the constituents of beer.

The fermentation of beer is the most critical part of the process of brewing, inasmuch as it is at this stage of the operation that the quality of the beer is chiefly determined; that is to say, at which its flavour, aroma, and other refined qualities, more valued by cultivated tastes than the mere proportion of alcohol (which only determines its intoxicating powers) are generated. If the operation be carelessly conducted, or, what amounts to the same, left entirely to itself, a bad-flavoured beer results, which may yet contain a proper quantity of alcohol; by which test alone, in certain places, the quality of beer is estimated. But, as above hinted, this should be a secondary quality, compared with flavour; the more esteemed varieties of which can only be obtained by a strict attention to cleanliness, temperature, and a number of other apparently minor matters, too often neglected by brewers.

The fermentation having been nearly completed in the large "fermenting-tuns," as they are called, the beer is drawn off, and allowed to complete its fermentation, and to subside in smaller vessels, before being closed down in casks for use.

Beer thus consists of an infusion of malt and hops, the soluble materials of which have been considerably changed by the process of brewing. Before saying anything further of the composition of beer, it will be well to direct attention to the following table.

The following table exhibits the composition of two examples of beer, lately analyzed :—No. 1 gave 519 grains solid matter (437½ grains=1 oz. avoirdupois) and 382 grains alcohol. No. 2 gave 424 grains solid matter, and 319 grains alcohol. The detailed composition was found to be :—

	No. 1.		No. 2.	
	Per pint. Grains.	Per cent.	Per pint. Grains.	Per cent.
Water	7982	89·78	8103	91·60
Alcohol	382	4·30	319	3·60
Grape sugar	184	2·07	111½	1·26
Acetic acid	7	·08	15	·17
Mineral matter	27½	·32	18½	·20
Albuminous compounds	60½	·68	44½	·52
Gum, colouring matter, &c.	247	2·77	234½	2·65
Weight of pint in grains	8890	100·00	8846	100·00
Specific gravity		1·016		1·011

By the above analyses it will be seen that the chief bulk and weight of beer is water, and that the amount of materials to which the effects of beer (over and above those of water) can be ascribed is very small; at the same time not much smaller than in some garden vegetables and fruits.

We notice that the chief constituent of beer is gum, or rather, an extractive matter analogous to gum. This substance is obtained on analyzing beer, as a dark-coloured substance, extremely tenacious and unctuous, and very retentive of moisture. This substance, with the alcohol and unaltered sugar, constitutes that portion of the beer corresponding to the starch of bread, and is, in fact, all that is left of the starch furnished by the barley, from which it has been derived. A considerable portion of this starch is accounted for in the carbonic acid gas, which has passed off in the fermentation.

It will be seen that the proportion of plastic materials in beer is very small: hence we cannot regard beer as any appreciable source of these compounds. Of the albuminous compounds originally present in the barley, that portion only which becomes soluble in malting (a considerable proportion, however) takes any share in connection with beer. Of this, the greater part is again separated in the production of yeast, which is very rich in nitrogen; so that we can thus account for the small proportion of nitrogenous principles in beer. In large breweries the surplus yeast accumulates, from this source, to an enormous extent; many thousand tons of it being used in a partially dry state as manure.

There also occur in all beer, variable quantities of acetic acid (the essential part of vinegar), which, if present in more than small quantites, imparts the disagreeable quality known as "hardness."

Besides these more abundant constituents of beer, others, present only in small quantities, take an important share in determining its character. Of these, the bitter principle of hops, as well as the essential oil from the same source, are, perhaps, the most valuable: there are also flavouring principles generated during the fermentation,—the nature of which, as already hinted, much influences the quality of the beer.

The bitter principle of hops also exerts a further effect, as is well known, in preserving the beer; an effect which seems to depend on its retarding the formation of acetic acid.

The mineral constituents of beer are, probably, amongst the most valuable of those contained in it. The ash of beer is particularly rich in phosphate of magnesia, a valuable salt of phosphoric acid, whose presence can be thus accounted for. The grain of barley, especially the bran, is rich in this substance; and as in the process of malting, and subsequent extraction with water, a good deal of it being soluble, it is not removed from the beer by any of the processes it is carried through.

The ash of beer (No. 1) contained 22 per cent. phosphoric acid, in the form of phosphate of magnesia and alkaline phosphates (phosphates of potash and soda). The ash of stout was found to contain 20½ per cent. phosphoric acid, similarly combined. It is not improbable that the presence of phosphoric acid in comparative abundance, and in an easily available form in beer, and especially porter, may help to explain the unquestionable benefit of the latter to mothers while suckling infants; since, at this period, an increased supply of this element of food is demanded in the secretion of human milk, of which it is a most important constituent.

Besides the above-mentioned solid and liquid components of beer, there also occur, dissolved in it, varying quantities of carbonic acid gas,—a constituent which confers much of its palatable qualities. The unpleasant taste beer acquires by prolonged exposure to the air, known as "flat," merely arises from the comparative absence of the gas, while the more agreeable taste and exhilarating effect of recently-drawn beer, and especially that recently taken from bottles, is mainly owing to the presence of this gas in considerable quantities.

The best kinds of beer are by no means the strongest. Moderately strong, or even weak beer, is, by proper management, made to possess all the qualities most esteemed in this beverage by cultivated people.

Some of the best sorts of bottled beer are comparatively weak; that is to say, the amount of alcohol they contain, is by no means proportionate to the price charged, which is demanded for perfection in condition and flavour, rather than for intoxicating powers. Again, in the above-quoted analyses of beer, the results (No. 1) represent an ordinary household beer, of very moderate price (one shilling per gallon, in quantities), but which is allowed to be by all who drink it, of the best possible quality as regards flavour, general palatability, and harmlessness. The two last columns in the foregoing table (example No. 2) represent a beer in every way the reverse of the above, although it contains but little less alcohol, and evidently costs as much in its production. These circumstances are sufficient to show that in brewing, as in every other human occupation, the result depends almost entirely upon the degree of skill and care taken in its performance. This is especially the case in brewing; for although, by adding together certain quantities of water, malt, and hops (or, in other words, by brewing mechanically), we may obtain a liquid that may pass for beer, and which will even contain a proper quantity of alcohol, a good beer can only be insured when the theory and practice of the process are thoroughly understood, and the whole carried out with careful watchfulness and a prompt attention to all apparently unimportant details. Although the quality of the water of particular districts has, no doubt, something to do with the quality of the beer made there, its quality may be controlled to a much greater extent than is commonly supposed possible.

PORTER AND STOUT.

Porter and stout differ from ale chiefly by their being more highly coloured, and by containing different flavouring principles, consequent on the different treatment the malt used for this purpose has undergone, and not so much by containing more solid matter, as we might suppose; since many perfectly bright ales contain as much solid matter as porter.

The malt used in making porter is more highly dried, or, in fact, is roasted; whereby soluble gummy products are generated, which impart the deep colour to this beverage. A different kind of hops is also used.

Stout of the best kind may be regarded as strong porter; but much of the bottled stout is no stronger than ordinary porter,—its superiority being due to the larger quantity of carbonic acid it contains, and the excellent condition it acquires by being bottled at a period found by long experience to be the best for insuring this condition.

The peculiar flavour of porter and stout is generally distasteful to persons unaccustomed to their use, which, no doubt, accounts for these drinks (the former more especially) being popular only in certain localities, as in London, where porter, being the prevailing beverage, is brewed in vast quantities.

The best draught stout is, without doubt, the best kind of beer that can be resorted to in cases where the strengthening properties of this liquid are desired. The unquestionable value of stout, when properly administered in certain conditions of the body, is, probably, to be chiefly ascribed to the mineral salts above mentioned. For the same reason, this liquid is unsuited to form an habitual beverage for persons in good health. A pint of excellent bottled stout gave 555½ grains solid matter and 560 grains alcohol. The composition was found to be:—

	Per pint. Grains.	Per cent.
Water	7766¼	87·44
Alcohol	560	6·32
Ash	40¼	·45
Albuminous compounds	42	·47
Acetic acid	3	·03
Gum, colouring matter, and sugar	470	5·29
Weight of pint	8882	100·00
Specific gravity	1·015	

It is, unfortunately, too true that beer, and especially porter, is much adulterated, particularly in large towns, where the temptations to, and facilities for this kind of fraud, are greater than in other places.

Of the adulterations used for this purpose, the commonest is "coculus indicus," a berry brought from the West Indies, and imported in considerable quantities, under the name of a medical drug, although its use in medicine is extremely limited.

The temptation to dishonest publicans to use this drug is very great, inasmuch as a small quantity produces effects on the human system analogous to alcohol, but is much more injurious: hence it allows of a weaker beer being substituted for a stronger kind. The admixture of this and other foreign ingredients with beer, and, indeed, the adulteration of food generally, are frauds which cannot be too strongly condemned; and it is to be sincerely hoped that, before long, effectual means will be adopted for their suppression.

WINE.

From the earliest times, wine has been esteemed as the rarest and choicest beverage procurable by mankind; and, notwithstanding the constantly-increasing difficulties of obtaining these fluids in their normal state, the above distinction may, perhaps, without any great impropriety, be applied to the better sorts of wines at the present day.

Probably no kind of commodity presents so many varieties of quality as wine; since we not only get a distinct species from each wine-growing country, but each district often furnishes several different sorts. These differences are to be ascribed not only to climate and soil, especially the former, but also to the mode of proceeding in the vintage and subsequent management. Without entering into any historical or commercial account of wine, we intend to point out the more interesting chemical facts connected with its production.

Grapes have been already mentioned as an abundant source of sugar, and of that kind of sugar which, occurring most abundantly in fruits, and especially grapes, is usually called grape-sugar. There also occurs in grapes a considerable quantity of albumen. The acid before mentioned (tartaric acid), and mineral matter, besides peculiar flavouring, and, in the skins of purple grapes, colouring principles.

So long as the juice is preserved in small quantities, with the air almost excluded, as in grapes in their natural state, it suffers but little change beyond a gradual loss of water, and consequent increase in the amount of solid matter; indeed, grapes may be almost dried to raisins on the vine, without any chemical change occurring. But, so soon as the juice, in quantities, is exposed to the air, it immediately undergoes a spontaneous fermentation, just as takes place in the case of beer, on the addition of yeast. The addition of yeast is unnecessary in the case of wine, because the grape-juice contains enough albuminous matter to allow of the spontaneous and rapid growth of this product.

The plan more commonly pursued, in making red wines, is to gather the bunches of grapes as soon as actually ripe, and to pile them together in large tubs, where they are allowed to ferment, being, at the same time, repeatedly bruised and stirred, in order to liberate as much of the juice as possible. The more active fermentation thus takes place in the presence of the skins, from which, during the process, a considerable quantity of the purple colouring matter becomes soluble, and thus transferred to the juice.

It is a common error to suppose that white and red grapes respectively produce white and red wine; this, however, is not the case, the colour of the wine being chiefly determined by the presence or absence of the skins during the more active fermentation, as above stated. Most of the white wine is made of purple grapes, the colour being avoided by pressing the juice from the skins as soon after gathering as possible. Even champagne, which is probably the least coloured of wines, is made of purple grapes; but great care is taken to avoid bruising the grapes (which are often plucked singly from the stem) during the gathering.

The more violent fermentation having subsided, in the case of red wine, the grapes, &c., are next transferred to the wine-press, from which the juice is conducted into casks standing in cellars, where the fermentation is completed. The subsequent quality of the wine is said to depend almost entirely upon the skill and celerity with which these early stages of the process are conducted.

The stems, skins, seed, &c., separated from the juice in the process of pressing, are technically called the "marc;" and, as it still contains a little grape-juice, this is generally obtained by adding water, and again putting it through the press. By this means, a weak liquid is obtained, of which a kind of "small wine" is made, which constitutes the common drink of the peasantry in the wine districts. The marc, thus exhausted, contains about a fourth of its weight of seeds or stones, which have been used as a source of oil. It is finally either dried for fuel or returned to the land, as manure for the vines. In other places the marc is used for making verdigris, by packing it away with copper plates, whereby the little juice it contains gives rise to acetic acid, which forms, with copper, the desired product.

A part only of the sugar originally present in the juice is converted into alcohol and carbonic acid by fermentation: a greater or less quantity is always left, the amount of which determines the sweetness, or "dryness," of the wine. The acidity of wine, due both to the tartaric acid it naturally contains, and to acetic acid, formed from the oxidation of part of the alcohol, is also lessened, or altogether concealed, by the amount of sugar present. Sugar is often artificially added with this object.

During the ripening of the wine in casks, a considerable quantity of the tartaric acid naturally belonging to it, especially if the stems have been left with the grapes during fermentation, separates with the potash also present as a salt, called bitartrate of potash, better known, when purified, as "cream of tartar." This substance forms incrustations on the inside of the wine-cask; and it being, at present, the only source of tartaric acid, is an article of some importance in commerce. It is imported under the name of "argol." The separation of this salt is due to the fact of its being less soluble in alcohol than water: hence, as the wine becomes richer in this product, the above salt slowly separates.

During the same process, some very curious products are generated, which determine, to a great extent, the commercial value of the wine. These products give rise to the so-called "bouquet:" they consist of peculiar ethers, formed by the action of certain acids on the sugar and other substances present. The formation of these ethers in the wine is, at present, but imperfectly understood; yet a few of them, like the flavouring principles of fruit, which they somewhat resemble, can be imitated artificially.

We may now supply a table for showing the approximate proportions of the more abundant constituents of a few of the best-known wines:—

GENERAL COMPOSITION OF WINE.

	Port.	Sherry.	Claret.	Champagne
Water	74	77¼	92—87	90—83
Alcohol	20	21	6—15	5—12
Sugar	5	1	trace	4
Acid	1	¾	2	1
	100	100	100	100

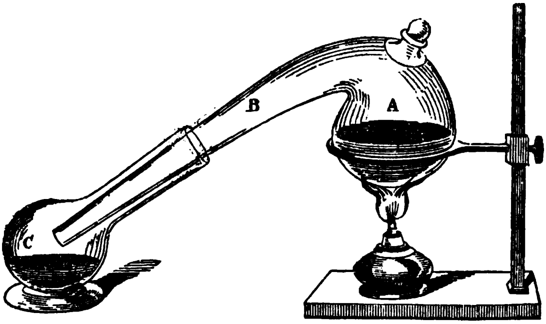
The much-esteemed peculiarities of champagne are secured by a mode of fermentation and management somewhat different from that above described. The grapes are gathered with every care, not only to prevent the admixture of colouring matter, as above noticed, but also to guard against the introduction of blemished grapes. Great care is also bestowed on its fermentation, in order to insure as much as possible the desired quality. Before the fermentation is completed, the wine is transferred to bottles, in which vessels it is confined during the whole of its subsequent treatment and ripening. By this means, a quantity of carbonic acid gas, which escapes in other cases, is retained, and gives rise to the peculiar effervescent properties so characteristic of champagne. As we have before noticed, carbonic acid will remain dissolved in liquids only so long as closely confined, and even then is limited by the strength of the vessel: thus, in the tedious management of champagne during its preparation for use, much loss is incurred from the bursting of the bottles; although champagne bottles are remarkably strong, yet the wine often gets too strong for them, and a certain proportion of bottles is always lost. It is somewhat curious that the best wine is that which has been nearest to the bursting-point, or, in other words, that is left amongst the bottles that have burst in greatest number. This source of loss in its production is, therefore, hardly sought to be avoided. The cost of preparing this wine is still further increased by the constant attention required to bring it to its marketable condition. It has to be re-bottled once or twice, and re-opened several times, to remove dregs, &c., before being finally closed down as fit for consumption. Notwithstanding the great price of champagne, its supply is considerably below the demand; so that all kinds of imitations are often substituted for it.

Port and sherry, in consequence of their being so much in demand, are amongst the most difficult wines to obtain in anything like purity. The former of these wines has long been notorious as the favourite drink of Englishmen, and even at the present day fabulous prices are occasionally paid for port wine when known to be of particular vintages. Most of the samples of these wines met with are more or less "fortified" by the addition of alcohol, an admixture alleged as necessary to satisfy English palates.

The Rhenish wines are probably the most wholesome and least adulterated. The large quantity consumed by the inhabitants of these districts, and their notorious good health, is the strongest possible evidence in favour of, at least, the harmlessness, if not the usefulness, of good wine.

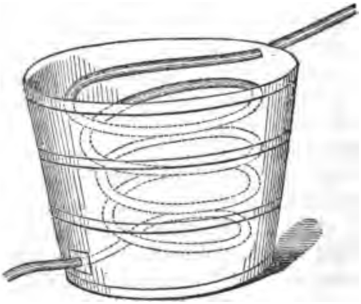
SPIRITS, LIQUEURS, &c.

If wine, beer, or, indeed, any fermented liquor of the kind, be exposed to heat, the alcohol which these liquids all contain may be driven out or volatilized, along with some of the flavouring principles they contain. This circumstance depends on the fact that alcohol is more volatile than water; alcohol boils at a temperature of 177° Fah., while water requires 212° Fah.: hence the two fluids may be approximately separated by exposing them to a temperature below the boiling-point of water, but above that of alcohol. Further, if we expose a liquid of this kind to heat in a vessel so contrived that the alcohol driven out as vapour shall be condensed, *i.e.*, deprived of its heat, and so reconverted into a liquid, we may obtain the alcohol thus separated in a fluid form. This process is called distillation, and is one that is frequently employed by chemists for separating liquids of different boiling points, &c. The same process has also received extensive application in a number of arts and manufactures, and is especially employed on a very large scale in the preparation of spirits for human consumption. This process is carried on in retorts or in stills, the principle of which may be gathered from the following sketch, which represents a retort and receiver for distilling on a small scale :—



The liquid to be distilled is boiled in the vessel A, and the vapour reconverted into liquid, by condensation, in the neck of the retort B, whence it runs into the receiver C.

In distilling larger quantities, a " worm-tub " is used to condense the vapour, which is generated in some sort of boiler specially contrived for the operation carried on.



A still, as contrived for distilling spirits in large quantities, is a rather complicated apparatus, for the reason that the heat produced in the furnace is made to do as much work as possible before it is dismissed.

By this process, liquids are obtained considerably richer in alcohol than the beverages we have so far referred to, and which are, consequently, capable of exhibiting in stronger colours all the curious properties of this singular compound: such liquids are the various spirits, cordials, &c., which we are accustomed to make use of.

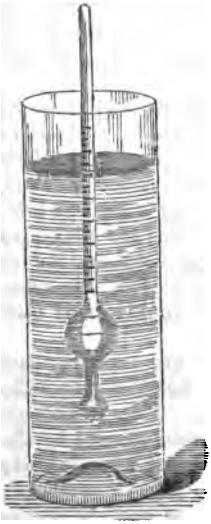
Spirits contain from 40 to 50 per cent. of alcohol; the rest is water. The characteristic flavour of particular spirits is imparted by minute quantities of essential principles, which are either added to the materials employed or exist in them naturally. Thus, brandy is dilute alcohol, containing some of the flavouring principles of wine; gin is flavoured with juniper berries, added to the liquid before distillation; whiskey is the flavour naturally obtained from grain, fermented and distilled under peculiar circumstances; rum owes its flavouring principles to pine-apples. Numerous other flavouring materials are used to produce the varieties of liqueurs and cordials which some persons indulge in.

The deep colour of some spirits is in no way essential to them, colour being purposely added, as in the case of cheese, merely to please the popular taste. The colour is imparted by means of a substance called caramel, commonly called burnt sugar. By heating sugar to a temperature of about 400° Fah., its properties are strikingly changed; it is now capable of imparting a rich red colour to liquids. The colour of porter is due to this substance, which is incidentally produced from the highly-dried malt used for making this kind of beer.

Spirits, even when much diluted, are certainly not wholesome as habitual drinks, nor so harmless generally as the liquids we have so far described. This is because the alcohol in these liquids, being unaccompanied by the other useful constituents present in beer and wine, is likely to exert its objectionable qualities too freely; moreover, it seems probable that alcohol which has once been concentrated as in spirits, exerts a different effect on our systems, even when again diluted, to what it does in dilute liquids where it has been produced.

But the peculiar qualities of flavouring and other principles in spirits probably modify to some extent the effects of the alcohol when taken in this form. We may infer this from the well-known fact of different kinds of spirits, which contain approximately the same proportion of alcohol, acting very differently on our system.

Apart from the use of alcohol in the form of spirits, its many useful qualities cause it to be consumed in large quantities in various arts and manufactures; and although for some of these purposes the baser wood naphtha may be substituted, in many cases alcohol is indispensable. In order to lessen the expense of alcohol, consequent on its excise restrictions, when used for these purposes, it is now sold free of duty under the name of "methylated spirit," *i. e.*, after having been rendered totally unfit for drinking by the admixture of a small quantity of wood naphtha,—methyl alcohol.



The strength of spirits, or the proportion of alcohol they contain, is subject to very strict excise regulations. The means commonly used for ascertaining the strength of spirit is by an instrument called an hydrometer, one that is extremely useful for a variety of other purposes in arts and manufactures, for ascertaining in a ready manner the specific gravity of liquids, *i.e.*, their weight, in comparison with some standard, as water, for instance. This useful instrument is simply a glass float with a graduated stem, for showing to what depth it sinks when placed in a liquid. Its principle depends on the well-known law; viz., that a floating body which stands at a certain height, or, in other words, sinks to a certain depth in a given liquid, will sink deeper, or will be more immersed, in any liquid which is lighter; and the converse. Thus, as alcohol is a considerably lighter liquid than water; hence, a float made to stand at a certain height in water will sink deeper in alcohol; and so, in a mixture of alcohol and water, as in spirits, the depth to which it sinks will show the proportion of alcohol present.

In this way the amount of essential material in many liquids can be very readily ascertained.

As is well known, proof spirit is the standard used to compare the strength of ordinary spirits. It has a specific gravity of 919; that is to say, a vessel holding 1000 ounces of water would contain only 919 ounces of proof spirit. It contains 49·25 per cent. real alcohol, and 50·75 per cent. water.

CIDER AND PERRY.

THESE beverages resemble beer in some of their qualities, but, on the whole, perhaps, have a nearer resemblance to the poorer sorts of wine. Cider is largely consumed in certain districts of this country, especially in Devonshire and Hereford, where, amongst the poorer classes, it takes the place of beer in other localities As frequently consumed in these places, it is excessively sour, unpleasantly so to persons unaccustomed to its use, but only called "hard" by those who take it habitually.

As every one is aware, cider is made from apples, the actual juice, however, only being used for the strongest cider: for ordinary cider, the juice is more or less diluted with water before fermentation. The acid taste of rough cider is due to the presence of malic acid, before mentioned as present in the apple, as well as acetic acid formed from the oxidation of the alcohol, as in the case of beer. In sweet cider, malic acid is also present, but its acid taste is concealed by the preponderance of sugar. It is the presence of this acid, in addition to that likely to be formed as above, that the great tendency of cider to turn sour, and consequent difficulty of keeping it, is to be ascribed.

The idea seems prevalent amongst cider-growers, that any kind of apples will do equally well for this purpose;

for we generally find in cider-orchards trees bearing no distinct variety of fruit, a prolific crop of apples, without regard to flavour, being the only object sought for. It seems probable, however, that by a selection of the apples employed, with greater attention to other minor matters, the above drawback might be much lessened, or entirely overcome.

The following is an analysis of cider made a few years ago : it represents the cider drunk by agricultural labourers in Devonshire ; and although it seemed at first disagreeably sour, it became, as one got accustomed to it, by no means a disagreeable beverage :—

COMPOSITION OF CIDER (COMMON DRAUGHT CIDER).

	Per cent.	Per pint.
Water	94·21	8292·41
Alcohol	4·17	367·69
Sugar	·35	31·67
Dextrine, &c. . . .	·51	45·05
Albuminous compounds .	·02	1·94
Acid	·54	44·86
Mineral matter . . .	·20	18·38
	100·00	8802·00 grains.

Vinegar.—In connection with the foregoing alcoholic liquids, we ought, perhaps, to mention vinegar, which, although very different in quality, and applied to purposes altogether different from the preceding commodities, is yet related to them chemically, inasmuch as it has its origin from the same sources. The well-known facility with which alcoholic liquids become sour and unfit for use is due to the formation of acetic acid, from the oxygen of the air combining with the alcohol, which thereby becomes acetic acid, the essential constituent of vinegar.

As is also well known, liquids of this character undergo this change the more readily in proportion to the extent of dilution of the alcohol ; so that the alcohol of weak wine, beer, &c., is much sooner oxidized into acetic acid than stronger liquids of the same kind. This is because the conversion of alcohol into acetic acid, like that of vinegar, is effected by the agency of a ferment which sets up this second fermentation, called, from its product, the "acetous fermentation." This transformation is influenced much by temperature, being greatly accelerated by a gentle warmth,—hence the greater difficulty of keeping such liquids in warm weather; and is retarded, or entirely suspended, by a reduction of temperature: hence also the value of cool cellars for keeping beer, &c. in summer time.

Vinegar is made of the weaker white wines, and also more extensively from malt, in a manner somewhat analogous to brewing; but the process is conducted so as to favour the acetous fermentation.

Pure acetic acid is a very strong acid, although much inferior in this respect to the mineral acids. The strongest kind congeals easily in large crystalline masses, like ice, and is therefore distinguished as glacial acetic acid. The taste of this acid, when much diluted, is a very agreeable acid. In table vinegar of the best kind there is generally about 5 per cent. acetic acid; the rest is water.

NON-FERMENTED BEVERAGES.

We have now to consider another group of liquid refreshments of an entirely different character to the preceding. It comprises tea, coffee, and cocoa; commodities now almost universally employed in this country as the liquid refreshments at morning and evening meals; and a few others.

TEA, COFFEE, COCOA.

Tea and coffee, though differing considerably, not only in flavour, but also in their physiological effects, yet possess many properties in common. They both contain (tea more abundantly) a peculiar body, which is believed to be their most essential constituent, and to which the refreshing effects of these liquids is, for the most part, to be ascribed. This body is called theine or caffeine,—its effects in tea and coffee being respectively modified by certain volatile flavouring principles, which also determine, in each case, the characteristic smell and taste of these beverages.

Cocoa, again (that prepared from cocoa nibs), although differing from tea and coffee in taste, &c., and also by containing a larger amount of solid matter, which, being of a useful character, renders cocoa superior to these liquids, if regarded as sources of nourishment, also contains an essential principle, but slightly differing from theine, called "theobromine."

These essential principles of tea, coffee, and cocoa, belong to an exceedingly curious group of organic compounds, called alkaloids. As these substances are of particular interest, not only in connection with the beverages we are now speaking of, but in other ways, a short account of them may not, perhaps, be out of place.

The compounds in question are called alkaloids, or vegetable bases; because, in their chemical properties, they bear a remarkable resemblance to the earlier-known alkalies and bases of the mineral kingdom. The alkaloids have, however, a very intricate composition, in which nitrogen seems to be the characteristic element. These compounds are amongst the most complicated products of organic life, and are also amongst the most potent in regard to human life and health; since all of them seem to exert a very powerful action on the entire frame, though, severally, in very different ways. While some of these bodies seem to be highly valuable constituents of food, as, for instance, kreatinine, already noticed in connection with meat, and to which we may now add the alkaloid of tea and coffee,—others exert a narcotic effect; indeed, the very extraordinary properties found amongst the various narcotics which men in all parts of the world have discovered and indulge in, owe their effects to one or more of these singular bodies. Thus, tobacco owes its virtue, in this respect, to nicotine; opium and laudanum, again, contain morphine, which is particularly interesting from the fact of its being the first of these bodies discovered.

Further, some of the alkaloids are invaluable medicines, such as quinine, veratrine, &c.; while others, and the majority, are deadly poisons; such as strychnine, obtained from a berry called nux vomica; aconitine, from the monks-hood, or aconite; and atropine, from the belladonna, or deadly nightshade.

As is well known, tea is the dried leaves of a shrub (the *Thea sinensis*) chiefly grown in China, where, from almost time immemorial, its leaves have been used for the production of the beverage now so universally used in this country by all classes. The two principal varieties of tea, viz. "black" and "green," are the produce of similar plants, differently treated. Black tea is partially fermented before drying; while green tea, being more rapidly dried, and altogether more carefully handled, retains the green colour natural to the leaf. This distinction, of course, applies only to the better sorts of black and green tea, since it is well known that a great deal of the green tea imported is coloured artificially. Other varieties of tea arise from peculiarity of climate, and other circumstances connected with its cultivation and management.

Black tea, as ordinarily consumed, has been found to have the following composition. We append coffee to the same table, for the sake of comparison :—

COMPOSITION OF TEA AND COFFEE.

	In a dry state.		*Infusion as usually made*	
	Tea.	Coffee.	Tea.	Coffee.
Water . . .	12	13·0	99·31	98·80
Theine . . .	1	·5	·54	·95
Nitrogenous matters .	25	13·0		
Essential and other oil .	4	10·0		
Tannic acid . .	12	5·5		
Woody fibre . .	22	30·0		
Gum, cellular fibre, &c.	19	21·5		
Mineral substances .	·5	6·5	·15	·25
	100	100·0	100·00	100·00

The ash of tea is rich in potash, phosphoric acid, and oxide of iron.

The preceding table plainly shows that the virtues of tea and coffee are certainly not to be ascribed to the amount of solid matter they contain, which is seen to be exceedingly small. The physiological effects of these liquids must, therefore, be owing to a peculiar and very potent action of the essential constituents, altogether different from the action of nourishment generally. At the same time, the amount of solid substance in these beverages is not so small if we consider the quantity of cream, or milk and sugar, usually taken with them.

The following numbers will give an idea of the increase of nutritive material obtained by the addition of sugar and cream to tea and coffee :—Seven fluid ounces of tea (the average capacity of a teacup) were found to require 240 grains, or about half an ounce of cream, and about 100 grains of sugar to render it palatable, according to an average taste. 10 oz. of coffee (the capacity of an ordinary coffee-cup), with the same proportions of cream and sugar, contain the following amount of solid food :—

	A cup of tea. (7 oz. liquid.)		A cup of coffee. (10 oz. liquid.)
Caseine, or cheesy matter, from cream . .	5	. . . .	7·5
Fatty substances, with little sugar, from cream	30	. . .	41·0
Sugar	100	. . .	140·0
Extract of tea . .	21	of coffee .	52·5
(Mineral substances 4·76 Organic matter 16·24)		(Mineral substances 10·75 Organic 41·7)	
Mineral substances from cream	1	. . . .	1·5
	157 grains.		242·5 grs.
	More than quarter oz. (109 grains.)		More than half oz. (219 grains.)

Theine acts on the skin, nerves, and system generally, in a manner not very well understood. In small quantities, as usually taken in reasonable quantities of tea of moderate strength, its action is, at least, not injurious, as we may fairly infer from the experience acquired by so many years' use. In larger quantities, however, as may easily be received into the system, when much strong tea is habitually taken, its action is decidedly injurious.

The essential oil imparts the agreeable smell of tea, and most of its esteemed flavour. The organic portion of tea is also rich in tannic acid, or tannine. It is this substance which imparts the peculiar astringent character to tea, and other vegetable products in which it occurs. The most interesting property of this body is that of its forming a deep bluish-black compound with salts of iron. Thus, if we add a crystal of sulphate of iron or green vitriol to liquid tea, we get the dark colour, the same that, in greater intensity, constitutes ink.

Another interesting property of tannic acid is that of its forming a very peculiar combination with animal membrane, whereby the latter almost loses its tendency to decay, and becomes quite insoluble in water. Animal membrane thus combined with tannic constitutes leather.

It will be seen that the mineral matter of this portion of tea is comparatively large, and contains the usual mineral elements of food. It is said to be rich in the mineral element iron, which, as we shall show in a subsequent chapter, is an exceedingly valuable constituent of food. The iron present in tea exists in a peculiar organic combination, which does not allow of its being converted into ink, as it otherwise would be by the tannic acid also present. We may infer that one of the benefits derived from the use of tea arises from its furnishing some of this valuable element, which is no doubt additionally serviceable from the above-named peculiar combination in which it occurs.

The practice of adding soda in making tea has the effect of extracting more of the albuminious compounds (which are all more soluble in dilute alkaline liquids than in water); but it is doubtful whether the additional quantity thus obtained compensates for the harm an undue quantity of soda is likely to produce.

The well-known refreshing and invigorating effects of tea are for the most part attributable to the peculiar action of the theine and essential oil upon the nerves and circulation, aided by the hot state in which it is usually taken, and, as above mentioned, can hardly be ascribed to the small quantity of nutritive elements it contains; yet these, in conjunction with the sugar and cream usually taken with tea, allow of its being included amongst the most nutritive beverages. As before remarked, however, beverages generally are to be regarded as necessary for aiding the assimilation of solids, or as luxuries, rather than as sources of nourishment. Another effect of tea is to retard the action of the vascular system; and thus economizes food. This effect is well known amongst the poorer classes, especially of females, who, in a mistaken use of it, are apt to injure themselves by a too constant use of tea.

Coffee resembles tea in so far as it contains the same alkalies (called indifferently caffeine or theine), but its effects on our system are, as already noticed, different. This is because the theine in coffee is smaller in quantity, and is accompanied by products which modify its action. These products are generated during the process of roasting, which, in fact, develops nearly all the characteristic qualities of coffee.

Unlike tea, coffee possesses no agreeable taste or smell in its raw state, and cannot be used until partially baked or roasted. The unroasted berries, or "beans," as they are technically termed, are woody, tasteless things, exhibiting no sign of the virtues capable of being developed in them by fire.

Coffee is the seeds of a handsome shrub, which bears them inclosed in a kind of pulp, the separation from which is said to be attended with considerable labour. The best Mocha coffee comes from Arabia, but most of that supplied to this country comes from Ceylon and the West Indies.

By cautious exposure to an elevated temperature, the peculiar aromatic oils are developed, as well as certain astringent acids, on which the peculiar flavour of coffee depends. The oil of coffee is volatile, and, therefore, most plentiful in coffee recently roasted and ground;—an excellent reason why coffee should be kept as short a time as possible after roasting and grinding.

The composition of coffee, both in a raw state and also of the infusion of ordinary strength, has been given with tea, in order that the two might be compared.

The effects of coffee on the system differ from those of tea chiefly by its retarding the digestion of food, in virtue of the empyreumatic products it contains. The custom of taking coffee immediately after dinner has no doubt arisen from the sense of relief it affords, by restraining the too vigorous action of the stomach when excited by stimulants. For the same reason, persons of weak digestion find it more to their comfort to take tea instead of coffee; since tea exerts no effect of this kind, but rather a contrary one.

Cocoa, although less generally popular than tea or coffee, is nevertheless to be ranked as equal, or even superior in some respects, to tea or coffee, at least in point of wholesomeness and fitness for domestic use. We suspect the reason why cocoa is less popular than the foregoing beverages, to be, that its peculiar flavour is not so agreeable as that of tea or coffee, but probably, also, because so many mixtures are sold under the name of cocoa, which, when prepared, obviously rank very low as human beverages.

As already remarked, cocoa also contains an alkaloid analogous to theine, called theobromine. It will also be seen that cocoa is exceedingly rich in respiratory and plastic principles of food; much more so than either tea or coffee: hence its superiority as a source of nutriment. The action of theobromine on our system is much the same as the allied compounds above spoken of.

It is exceedingly curious that the vegetable products that in different parts of the world have been discovered to possess refreshing virtues when infused in water, and used as beverages, should contain theine, or some alkaloid closely analogous to it.

The following remarks are intended to apply more particularly to the true seeds of the cocoa-plant (*Theobroma Cocoa*), or what, when freed from husks, roasted, and bruised, constitutes the cocoa nibs. This is undoubtedly the best source of cocoa, although some of the better sorts of prepared varieties are preferred by many persons.

Chocolate is merely the best cocoa carefully roasted, ground up with sugar, and flavoured with vanilla. The flake, rock, soluble, and other prepared cocoas, consist of the cocoa nibs ground up with fat, starch, sugar, and various other ingredients.

The composition of cocoa is as follows :—

COMPOSITION OF COCOA (COCOA NIBS).

	In ordinary state.	A decoction made in usual manner.
Water	15·56	97·88
Theobromine	·50	1·93
Albuminous compounds	15·06	
Solid and liquid fatty matters	36·68	
Cellular tissue, gum, and other non-nitrogenous compounds	24·04	
Woody fibre	5·20	
Mineral substances	2·96	·19
	100·00	100·00

The decoction was made in the manner commonly pursued in preparing this beverage; viz., by adding two teaspoonfuls of the bruised cocoa to every pint of water, and stewing the mixture some time before using (in this case about twelve hours). By this treatment the liquid loses about one fourth by evaporation.

Ten oz. of fluid, or a breakfast-cup of this beverage (of the above strength), would contain, supposing the same quantity of sugar were added as in the case of coffee, but milk substituted for cream—

		Grains.
Extract from cocoa		93
(containing fatty matter	24·5	
„ mineral substances	8)	
Sugar		140
Caseine from milk		15·5
Butter and sugar from milk		27
Mineral substances from milk		2
		277·5 = ½ oz. + 58 grs.

On comparing this beverage with the preceding, it will be seen that it contains more solid material, and is therefore, on the whole, a more nutritive beverage. It is certainly a more economical one, and is therefore worthy of greater patronage from the poorer classes. Its greater economy than tea or coffee depends not only on its yielding a more nutritive beverage, but also from the fact that the "bean" or berries themselves, especially after stewing, as in preparing this drink, may be ranked amongst wholesome solid food; while the same cannot, of course, be said of the residue left from making tea or coffee. It is true we hear of tea-leaves being eaten in some parts of the world, and were even, we believe, eaten in this country when tea was first introduced, and esteemed, perhaps, as a not very palatable but expensive delicacy (as olives are by many persons nowadays); but their claim, and still less that of coffee-grounds, to the title of wholesome or even eatable food, seems to be very questionable.

However, the composition of the tea or coffee (the dry substance) is of little consequence, seeing that we extract from them but a minute quantity of essential matter, altogether insignificant as actual food. But this is not the case with cocoa nibs, every part of which is wholesome food, although not liked by some persons; in fact, chocolate is nothing more than cocoa nibs ground to an impalpable powder with sugar and flavouring principles. By stewing the cocoa for a considerable time (merely leaving the grounds in the pot instead of removing them when fresh is added), and especially by rebruising, it yields a much larger quantity of an excellent beverage than either tea or coffee.

The superior nutritive value of cocoa induced me to make an examination of the ash for phosphoric acid, and I found, as the annexed result shows, a large proportion of this valuable substance, which no doubt in part accounts for the nutritive value of cocoa:—

COMPOSITION OF THE ASH OF COCOA.

Alkaline salts (salts of potash with a little soda)	44·56
Containing phosphoric acid (3·33)	
Phosphate of lime	36·24
Phosphate of magnesia	18·38
Silica	·82
	100·00

A few other liquids, belonging to neither of the foregoing groups of beverages, must now be noticed, to render this part of our subject complete.

Water must certainly be included amongst human beverages, as, apart from the priceless value of this extraordinary mineral fluid in relation to our bodily economy, as well as numberless domestic operations (in both of which characters we shall have more to say about it in a future chapter), it being preferred by a large number of persons to beer, wine, &c., is a sufficient reason for our noticing it here in the character of a beverage.

The varieties of water met with in different places are almost as numerous as those of either of the preceding commodities. At present we need not inquire into the causes of this, but we mention the fact because it is when used as a direct beverage that such differences are most apparent. We say direct beverage, because it will have been seen from the foregoing analyses that every kind of drink commonly used (except, perhaps, ardent spirits, which can hardly be considered in this light) consists for the most part of water.

The question of whether it is better to take the water we require in a crude or natural state, or in any of the more palatable liquid mixtures referred to in the foregoing pages, we have no intention of discussing. We may remark, however, for the information of water-drinkers, that many impurities commonly occurring in water are more likely to be injurious when the water is taken directly than when in the shape of prepared liquids.

The impurities we allude to are those of an organic origin, such as animacules and fungi. These are destroyed, or at least rendered inert, by the scalding temperature the water is exposed to during its conversion into the majority of fermented or non-fermented drinks.

The selection of water for drinking requires almost as much care as the selection of more expensive beverages; at least so consumers of this beverage say. A wholesome and well-flavoured water is certainly by no means common.

Good drinking-water should contain but little solid matter of any kind, and this of a harmless character. It should especially contain but a trace of organic matter, and this should be of a non-nitrogenous character (free from sewage and drainage).

We need hardly add that all water used for drinking should be filtered before using; but it should be understood that filtration is but a poor protection against bad water.

Spring-water is generally the best for drinking, when it can be had; as this kind of water seldom contains organic impurities, and is generally agreeably charged with carbonic acid gas. It may be mentioned that many of the pumps in the streets of London and other cities, reputed to furnish spring-water, derive their water from surface-wells, which is often of the worst character for drinking, being charged with coal-gas from the gas-mains, nitrates, and other impurities we shall have to mention in speaking of water as a domestic agent.

In most of the effervescent drinks commonly used, such as ginger-beer, lemonade, soda-water, &c., the effervescence and other general qualities result from the sudden relief from confinement of carbonic acid gas in the manner already described. The liquids are charged with this gas either by an incipient fermentation, as in ginger-beer, or more commonly by being charged with this gas from some mineral source, in strong vessels, from which it is transferred to bottles, after being variously mixed and flavoured. Soda-water is simply water highly charged with gas, and seldom contains any soda,—its name being derived from an old method of preparing it with soda. Although soda-water, as generally used, can hardly be included amongst domestic beverages, weaker varieties of it are at present much used as summer drinks.

As previously mentioned, the presence of carbonic acid in liquids adds much to their refreshing qualities, without, in any reasonable quantity, detracting from their wholesomeness. By means of small aërating machines, now easily obtainable at a moderate price, almost any kind of liquid may be rendered effervescent.

The gas generated in these machines is generally obtained from a mixture of bicarbonate of soda and tartaric acid. These materials do not mix with the liquid to be aërated, the gas liberated from them only doing so. This circumstance constitutes an important advantage in favour of the liquids produced by these machines, over all effervescing draughts in which the products of the acid and soda (the basis of all mixtures of this kind) are swallowed with the liquid. The product formed in all cases where carbonate of soda is decomposed by tartaric acid, is a salt called tartrate of soda; a salt, although not perhaps actually poisonous, exceedingly unwholesome, especially when habitually taken in the quantities necessarily swallowed in these draughts.

In using aërating machines of any kind, it must be borne in mind that their use is not altogether free from danger, as several serious accidents have arisen at different times from their having burst while in use, the cover of wire or wicker-work commonly enveloping them being quite useless in the event of their exploding. Little danger need, however, be apprehended, if the quantities of soda and acid given in the directions (furnished with the machines) be not exceeded. It is also advisable to keep them in a cupboard or some closed receptacle when charged.

CHAPTER IV.

AIR AS FOOD, &c.

WHAT we take into our system every moment of our lives in the act of breathing, may, we think, without any unreasonable stretch of the imagination, be termed aërial food.

The justice of this title will perhaps not be disputed when it is remembered that air is as indispensable to our existence as the solid and liquid food we have so far been speaking of, while it is even more immediately essential, because these latter commodities are required only at intervals, and a deprivation of them for some days, though productive of much suffering and injury, does not necessarily deprive us of life; whereas, in the case of the aërial food we are about to consider, it is absolutely necessary that its supply shall be incessant. Although we are all perfectly aware that the continuance of breathing is an inseparable accompaniment to the continuance of life, yet we often seem to forget that the act of breathing is merely a consequence of the necessity of a supply of air to our bodies; just as the periodical appetite for food or drink arises from the necessity of certain materials which these commodities supply.

The internal economy of our bodies is, as we shall point out in the next chapter, intimately connected with the air that surrounds us, a large and constant supply of it to the blood being one of the conditions upon which the action of all functions more or less depends.

The breathing organs are merely the peculiar channels through which this necessary is supplied, just as the digestive organs are those by which our bodies are furnished with the various solids and liquids described in the preceding chapters.

Thus, we must admit that air is, at least, as important as solid and liquid food; and it is only because it is usually supplied in unlimited quantities, that we naturally think less of it than we do of those more palpable necessaries of life which can be procured only by payment or by labour of some sort or other.

Although air cannot, of course, strictly speaking, be said to take the place of other kinds of food, it is astonishing how far it goes towards doing so; since, if we have an abundant supply of good air, we may live, and even thrive, upon coarse food, that would otherwise be utterly incapable of supporting life.

We notice this in the case of seamen, who, although often fed on the coarsest and least wholesome diet, yet, as a class, are remarkable for robust health. Again, the case of agricultural labourers furnishes another example. These persons are in many districts obliged to subsist upon a meagre diet often inadequate to their wants, and only capable of sustaining life with an abundant supply of good air, such as they usually obtain.

On the other hand, no amount of good living can compensate for a deficiency of air; indeed, the more food we consume, the more air we must breathe, to insure its being properly disposed of in the system, or to prevent its doing mischief if more than enough has been taken. The truth is, that the food we take can only do duty in conjunction with air; so that a much smaller quantity of food than is generally supposed to be necessary, will suffice to maintain our bodies in health, if plenty of air be forthcoming.

Again, the quality of this kind of food exerts as great an influence on our well-being as that of the more ponderable necessaries we have made ourselves acquainted with. It is upon this point especially that the ideas of many persons are undefined. While most of us have an impression that some useful purpose is performed by the air in the act of breathing, comparatively few are aware of what this purpose consists; in other words, how the air ministers to our internal economy.

Bad air is as injurious, and sometimes far more so, than bad or unwholesome food; and if its objectionable character were as palpable to our senses, we should certainly as promptly reject dirty or foul air as we do suspicious-looking or unpalatable food or drink.

We meet with air of every degree of quality in respect to its fitness to be breathed, though these differences cannot always be easily distinguished.

The air found in the open country, away from any local sources of contamination, is usually good pure air, *i.e.* air in every way suited to fulfil its destined purpose in relation to animal life. Again, the air of the sea, or at the sea-coast, is of still better quality for persons generally than that which has blown over any extent of land. Sea air is always moister, and contains minute quantities of the various salts of sea-water, as well as being peculiarly rich in a curious body, ozone (presently to be spoken of), which renders it the best kind of air we can procure.

The great mass of the atmosphere of the globe consists of what we may call good or normal air, all kinds of bad or impure air being for the most part of local origin, and, in the majority of instances also, in this climate at least, are the creations of man. There are, however, differences of quality even in good or normal air, especially in the amount of moisture it contains. These differences are often so slight, as to be palpable only to persons suffering from complaints which render them peculiarly susceptible to influences of this description.

The air of towns and cities is always more or less generally deteriorated by coal-smoke and various impurities we shall presently have to speak of. Again, the air of dwelling-rooms, and especially sleeping-rooms, is also additionally impure, from the presence of certain products generated by the breath. But these, and all similar kinds of general impurities, are harmless, in comparison with those of local occurrence, which emanate from accumulations of putrefying animal and vegetable matter: amongst these latter are found the worst classes of aërial impurities.

Unfortunately, the quality of the air we breathe is less under our individual control than that of the food we take. We can always refuse to eat anything that, in our judgment, seems unfit to be eaten, and can thus escape much inconvenience and injury that might arise from unwholesome food. But against the many evils likely to arise from bad air, we are not so well protected; we are often compelled to swallow all kinds of bad air, and thereby obliged to suffer in comfort and health, from the ignorance or negligence of our neighbours; at the same time, aërial impurities, being for the most part of an insidious character, we often inflict injury by them upon our neighbours and upon ourselves unconsciously.

We have now to speak more in detail of the nature of aërial food; or, in other words, must describe the chemical properties of air, in so far as they relate to our physical well-being.

The mixture of gases constituting the atmosphere forms but a thin film or layer of light matter enveloping the planet which forms our material world. Yet, small as is the atmosphere, in comparison with the earth it incloses, it forms, as we are all aware, a medium of vast extent.

The air is supposed to extend upwards to a height of several miles; but a very small portion only of its lower stratum is adapted for respiration. We live in, and are surrounded by air in precisely an analogous manner to what fishes are in water,—with this difference, however, that we live at the bottom of our medium, while fishes (in relation to the water of the globe) live at the top (that is, near the top) of theirs.

Aërial food differs from either of the groups of substances dealt with in the preceding chapters, chiefly by being very much simpler in composition, and by being *inorganic*. Solid food, either animal or vegetable, owes its nutritive value, as we have seen, to peculiar organic compounds, which have been prepared by the agency of the inferior animals and plants, and as which compounds *only* the elements of these commodities are serviceable as food. The air, however, contains no such compounds by which its value is determined; its constituents are in a free or *separate* state, in which condition *only* are they serviceable to us in breathing.

The value of air in regard to us is manifested chiefly in connection with the essential principles of food, as before hinted. It seems to be the means by which the hidden virtues of solid food are developed in our bodies. At all events, by its action upon the constituents of food, we obtain warmth, strength, and other phenomena requisite for the preservation of our bodily structure.

COMPOSITION OF AIR.

Air has been collected from all parts of the globe, over land and sea, and, by means of balloons, also from all heights from the surface of the earth, and carefully analyzed. The results obtained show a remarkable similarity, sufficient to show that the general composition of the entire atmosphere is very uniform throughout its immense extent. The one component of the air to which all its primary effects are owing, is oxygen gas. Oxygen, when separately obtained, resembles common air as closely as possible in all external characters; but it possesses all the properties of air in a much higher degree, and it may, in short, be called the essential principle of air.

Oxygen has been facetiously called the sheet-anchor of popular lecturers, and it probably has been the most ill-used of the chemical elements in this respect; but, notwithstanding, its properties are so truly wonderful, and so intimately associated with ourselves and the entire system of nature, that we can hardly overrate the extraordinary properties of oxygen, or say too much in its praise.

If we may judge of the relative importance of the materials of the earth by the extent of their usefulness in connection with the animal, vegetable, and mineral kingdoms, we must certainly place oxygen first on the list, since it occurs in each of those departments of nature more abundantly than any other element, and in by far the greatest variety of form; indeed, in the aggregate, it forms as large a portion of the entire globe as all the other materials put together.

A better idea of the extraordinary abundance of oxygen may, perhaps, be gathered, when it is known that oxygen forms one-fifth of the atmosphere, eight-ninths of water, and, on the average, one half of the mineral kingdom. Moreover, of animals it forms three-fourths, and of vegetables four-fifths: hence we may safely estimate its quantity as from one half to two-thirds of the entire globe.

Oxygen is also the motive agent, so to speak, in nearly all natural processes, and others going on around us; such as combustion, decay, fermentation, &c.; as well as the more important one, respiration, upon which the present subject especially bears.

What we have called aërial food, or air, consists of oxygen diluted with another indifferent gas (nitrogen), to such an extent that its properties shall be modified to suit the requirements of our system.

Air, in its natural state, contains in one hundred parts,—

	By measure.	By weight.
Oxygen	21	23
Nitrogen	79	77
	100	100

Nitrogen, as it occurs in the air, seems to take no part in regard to animal and vegetable life, beyond this important office of diluting the otherwise too active oxygen. There is also present in the air more or less water, in the shape of steam or vapour; also small quantities of carbonic acid gas, which we shall presently have to speak of, and a few other substances in minute quantities, which, having no direct connection with our present subject, need not be mentioned.

The action of oxygen, in relation to our internal economy, as aërial food, depends, as already stated, on its being in a free or uncombined state; whenever otherwise, it is at least an encumbrance, being then useless as aërial food, but is often additionally injurious.

In breathing, we use up the oxygen of the air; because, by its sojourn in the body, it loses its free condition, and, therefore, becomes unfit for further use in the same way: hence every breath we take diminishes the quantity of available air at our command.

CONSUMPTION OF AIR IN BREATHING.

We may now explain how the oxygen received in the air inhaled loses its free condition, and thereby becomes useless.

Of the large quantity of air we have mentioned as being required in our bodies, and conveyed there in the breath, the greater part, when its duty is performed, is again expelled through the same channel. This duty consists, for the most part, in carrying away certain compounds of carbon and hydrogen existing in the blood, and originally supplied to the system in the solid form. These compounds, when brought in contact with free oxygen, under certain circumstances, are oxidized; that is to say, they combine with it, and as the resulting combinations are invisible gases, they are capable of being carried away invisibly in the breath exhaled.

Thus the breath we *inhale* and the breath we *exhale*, though apparently alike, are in reality very different; the latter containing the products of oxidation above spoken of.

The above process constitutes the extraordinary and beautiful process of respiration,—one of the natural processes, by the way, which chemistry has gone far towards elucidating. The purposes carried out by this process will be more suitably explained in the following chapter; for the present we have to deal only with the products arising from it, but may remark, in passing, that the process is of vital importance to our well-being, and is the object for which a large portion of the food we consume (the respiratory principles) is required.

Whenever oxygen combines with carbon and hydrogen, as in the case here under notice, it forms respectively carbonic acid and water. Carbonic acid is an oxide of carbon; water is a corresponding oxide of hydrogen. Of these two products, the former is always the more abundant in the breath, not only because carbon occurs in greater quantity in the oxidizable materials in the blood, but also because the accompanying product (water) being a fluid, remains in the system with the water supplied from the liquid food, the water found in the breath being probably furnished indifferently from either of these sources.

Carbonic acid being an invisible gas like the air, we do not perceive its presence in our breath, nor can we, under any circumstances, recognize by our unaided sense the carbon or charcoal contained in it. We say carbon or *charcoal*, because charcoal is the nearest approach commonly met with to pure carbon.

It is difficult to persons unacquainted with chemistry to realize the fact that carbon, charcoal, or we may even say soot, is continually passing off in the breath we exhale; yet a beautiful experiment can be shown (too complicated for description here) for producing visible, black carbon from transparent carbonic acid, such as may be collected from the breath.

Air after respiration consists of—

	By volume.
Oxygen	15
Carbonic acid	5
Nitrogen	80
	100

Thus the oxygen diminishes one-fifth to one-fourth; while the carbonic acid gas is increased about 100 times.

As regards the actual quantity of air required, we may arrive at an approximation to this by assuming that a person inhales 30 cubic inches at each inspiration, and as the average number of respirations is sixteen per minute, we get 480 cubic inches of air as the quantity consumed in a minute, or about 17 cubic feet per hour, or, in the twenty-four hours, about 400 cubic feet. This quantity would be contained in a closet or small room about 10 feet long by 6 wide and 7 high.

It must not, however, be supposed that a person confined in such a space for this period would be properly supplied with air; on the contrary, he would, under these circumstances at least, suffer great inconvenience, or more serious results. This is the quantity of *fresh* air actually required to be taken into the lungs, and not the quantity required to be supplied to our rooms. A much larger quantity than this is required to effectually remove the air expired.

It is clear that we *expire* as much air as we *inspire*, although its composition is very different, as we have seen. Now, if the air expired be allowed to mix with that which has not yet been breathed (as would be the case in a closed space), the latter soon becomes unfit for respiration, in consequence of contamination by the former.

The quantity of carbonic acid thrown off in the breath may be calculated as follows: the quantity of air expired in one minute, which we have assumed to be 480 cubic inches, contains 24 cubic inches of carbonic acid; in an hour we should have produced 816 cubic inches, or, in the 24 hours, about 20 cubic feet, containing about 10 oz. of carbon, or soot.

From this it is easy to see that the quantity of carbonic acid produced where many persons are together, amounts to something considerable, and we cannot wonder at its presence being felt more or less unpleasantly in crowded buildings, where no adequate supply of air for its removal is provided. Thus, in an assembly of 1,000 persons, there would be produced in an hour 480 cubic feet of carbonic acid gas, containing 131 lbs. of carbon, or soot; if this were only visible, how much more careful we should be to provide for its removal! When we further learn that gas-lamps, and all other ordinary sources of illumination, give off this gas in a much greater quantity, we can understand the necessity for a free circulation of air through our dwelling-rooms. Hence two conditions are necessary in order that the air breathed may exert the beneficial effects it is intended to exert towards us; one being a constant supply of new air adequate to the demand; and, second, a complete removal of the old air, or that which has been breathed.

If these conditions be not complied with, not only inconvenience but more or less injury results; since carbonic acid must be regarded not only as an encumbrance, or as a body taking up the space of available oxygen, but also as a deleterious substance. It exerts a peculiar injurious action on the system when retained therein, or when accidentally inhaled, beyond that arising from its preventing access of the ever-necessary oxygen. It is somewhat curious that these injurious effects of carbonic acid seem to belong to it only when inhaled; its presence in large quantities in fermented drinks, &c., as already noticed, furnishes sufficient evidence of its harmlessness when received into the stomach.

The headaches, drowsiness, and other unpleasant symptoms frequently experienced in crowded rooms and badly-constructed places of public resort, are for the most part caused by this gas in small quantities; and although such effects cannot be said to be injurious, they yet interfere with our enjoyments, and often give us unnecessary pain and annoyance. Considering the great discomfort, to say the least, which arises from this source, and the comparative facility with which an effectual ventilation can be established, it is extraordinary how few of our public buildings are properly managed in this respect.

The unpleasant or injurious consequences likely to arise from inhaling for several hours an atmosphere more or less charged with carbonic acid are not, however, only incurred by those who frequent ill-ventilated places of public resort, but are quite as frequently suffered by persons who spend most of their time in-doors.

In our anxiety to avoid our enemies—the draughts—

we too often shut out our best friend, fresh air. While it is certainly desirable to avoid all violent currents of air, especially when heated, it is quite irrational to close up every opening in our rooms, in an unfounded fear of them. The chief difficulty which besets any attempt to ventilate dwelling-houses, especially those of the humbler classes, arises from this propensity on the part of the inmates to stop up every accessible opening where the air enters.

Even cultivated persons often do themselves much injury (which is laid to the blame of everything but the right) in their anxiety to make their rooms—sleeping-rooms especially—" comfortable ;" an expression which, in reality, often means making the air of these rooms as unfit to be breathed as possible.

If, from any untoward circumstance, many persons occupy a confined space, the carbonic acid from their breaths, by accumulating in large quantities, produces far more disastrous results than the above. As is well known under these circumstances, the most painful sensations are followed by insensibility, and even death; an event heard of from time to time as the result of accident, but, in truth, of most culpable ignorance.

Disasters of this description have occurred at different times in emigrant ships, where, from efficient ventilation being seldom provided for, these occurrences are especially liable to happen, when, from bad weather or otherwise, the ordinary channels for the admission of air are closed. Another notorious disaster of this kind, now an historical event, is that in connection with the Black-Hole of Calcutta. Similar accidents are not unfrequently heard of as arising from the same properties of carbonic acid gas generated from other sources; and the fatal results which often attend these casualties are mostly to be ascribed to the reluctance, or even refusal, on the part of the sufferers, to believe in the potency of an invisible substance. Hence men rashly enter places rendered dangerous by the presence of this gas, and fall victims to their temerity. We may add by the way, that it is for the same reason that aërial poisons generally assail us at so great an advantage.

Wells, pits, and all low-lying cavities, are likely to become filled with this gas, which, from its greater weight in comparison with the air, is very likely to collect in places of this description. Again, brewers' vats are extremely liable to become dangerous to life from the same source, as, from the large quantity of carbonic acid generated from beer, these receptacles often become filled with an atmosphere containing dangerous quantities of carbonic acid gas. The best plan of rendering places in this condition fit to be entered, in the absence of any efficient means of blowing air through them, is to lower into them a quantity of recently slaked lime, which rapidly absorbs carbonic acid; or, a still more ready plan, applicable in certain cases, is to lower into them a mass of blazing straw or wood-shavings, which, by creating a draught, expels the foul air. We may also add, that carbonic acid gas constitutes the "choke-damp" or "after-damp," which is even more destructive to the lives of the poor coal-miners than the "fire-damp," or light carburetted hydrogen, presently to be noticed.

VENTILATION.

The before-mentioned necessity for a constant supply of oxygen to the system, and the objectionable qualities of carbonic acid, into which oxygen is changed, not only by our breathing, but by the burning of fires, lamps, and candles, make it evident that a free circulation of air through the rooms we inhabit is highly desirable, and, to some extent, absolutely indispensable.

The means of effecting this circulation of air, in a manner that shall be effective at all times and seasons, and at the same time unobjectionable as respects draughts, constitutes the art of ventilation. The subject of ventilation being a somewhat extensive one, we shall merely glance at a few general facts concerning it.

It being a rule, with scarcely an exception, that we cannot have too much air, provided we do not get it in the shape of draughts, it is clear that the more of this invaluable commodity we can supply to the rooms we inhabit the better.

It can hardly be denied that the superior healthiness of all out-door occupations, compared with those which are sedentary, or which are carried on in-doors, is for the most part attributable to the greater freedom with which air is obtained under these circumstances.

Even in large towns and cities, where the entire atmosphere is always more or less impure, the same rule holds good; because, however bad the external air may be (except from the presence of some unusual impurity), the air of rooms, &c. where people live, will always be worse, from the regular process of deterioration always proceeding there, under the most favourable circumstances, as already pointed out. Further, as the atmosphere of dwelling-rooms, shops, &c., seldom circulates sufficiently, and is often stagnant, all impurities there generated, have time and opportunity to exert upon the inhabitants any injurious effects they may be capable of.

Even in the streets of cities, excepting, perhaps, in the most ill-built and crowded ones, there are generally found occasional gusts of wind, which tend to freshen the air, while in-doors no such relief is afforded; and since the human system is much better able to bear an occasional breath of impure or even poisonous air, amongst that which is good, or even moderately good, than a prolonged exposure to an atmosphere but comparatively slightly tainted, we perceive the benefit of there being a free communication between the external air and that of the comparatively limited space we inhabit while in-doors.

The necessity of air being admitted by all cultivated persons of the present day, we seldom find any public building in which there is no attempt made to provide for a supply of this necessity; although, as before hinted, these attempts are but seldom effectual, and often wholly useless.

It is commonly supposed that if some vent is provided at the upper part of any large chamber for the escape of foul air, all has been done that is needful in the way of ventilation; the necessity for providing for the *supply* of air being too often lost sight of. It is true that with this simple arrangement the consumed air will for the most part escape through such a vent; but with no special provision for the *incoming* air, this enters wherever it can, through doors and windows, or whatever openings communicating with the external air afford the nearest channel. As the halls, staircases, and passages used for ingress and egress to the building generally also offer, in these cases, the readiest means of entrance for the air, it rushes along these places in masses; and hence draughts are unavoidable. At the same time the remoter parts of such buildings are always insufficiently supplied with air, as they can derive little or no benefit from any arrangement which allows the air to enter at a few places in masses.

In all in-door places of public resort, the supply of air should be quite independent of doors and windows. It should be allowed to enter at or near the floor of the building, through finely-perforated gratings, sufficiently numerous to allow of the new and colder air which enters by them becoming sufficiently divided, and at once mixed with the air already present, to prevent its difference of temperature being felt. Such supplies should also be drawn directly from the external air, at those parts of the exterior of the building where the best air is to be got.

In private dwelling-rooms provision for the supply and exit of air is still less frequently found than in public buildings, although, of course, such provision is generally less needed, from the larger proportion of space to the number of inmates, and from the action of other unintentional means of ventilation presently to be mentioned.

In the planning of houses, almost as much regard should be had to a supply of air as to a supply of water, or to drainage, as, unless this matter be had in view from the commencement, it is seldom that a good arrangement for ventilation can be effected. In the better sorts of modern houses we often find provision made for this purpose; but a proof that ventilation (if we allow the term to embrace the entire control of all currents of air passing through a building) is but little understood by architects and others responsible for the designs of houses, is afforded by the fact that in the best of modern houses, and even in cases where no expense has been spared in their erection, the nuisance of smoky rooms prevails to a great extent. The frequent occurrence of this nuisance in such cases reveals the truth, that the laws which govern the currents of air through our houses and other buildings, are not sufficiently understood. This is the more to be regretted, since the endeavours to remedy the annoyance of smoky rooms by external appliances to the chimney-tops, often mar the effect of the finest architectural design.

But, putting aside the question of smoky chimneys, which, perhaps, does not strictly belong to the subject of ventilation, as even the best of chimneys occasionally smoke, from, at present, thoroughly unexplainable, causes, it is in the dwellings of the poorer classes of towns, where the proportion of space to inmates being more limited than in the cases above supposed, an effective ventilation is most needed, but unfortunately, least seldom found; for obvious reasons.

In summer time but little special provision for ventilation in living-rooms is required, because, at this season, we instinctively throw open our windows whenever the weather will permit, and by this excellent custom obtain an abundant supply of air. In winter, however, no such provision exists, and our welfare in respect to air is mostly a matter of chance. In winter, however, even when we are most particular to "keep the cold out," by securely closing all doors and windows, we are cared for in this matter in a way we seldom calculate upon. A circulation of air, more or less perfect, is always maintained whenever an ordinary open fire-place is in operation.

However much we may find fault with the open fire-place on the plea of waste of fuel, which is said to warm the chimney instead of the room, we must certainly allow that this, and other minor defects, are more than counterbalanced by the excellent means it affords for ventilation. A brisk fire burning in a grate will always ventilate the room, by drawing up the chimney an abundant supply of air, which flows over the fire, beyond that necessary for combustion, which passes *through* the fire. The quantity of air thus carried from the room is replaced by the air out of doors, which finds its way into the room through the cracks of the doors, and through any other chinks or spaces that may happen to exist. An open fire is thus of much service, over and above the comfort it imparts by its warmth and appearance.

Of course, this result will not happen if the fire "draws" badly or smokes; the latter result, especially, overcomes all good which we otherwise obtain from a fire in this way; because the atmosphere of the room now becomes charged with all kinds of unpleasant and injurious products, arising from the imperfect combustion of coal. But we often condemn a chimney for smoking, without giving it a fair chance to draw. This is especially the case in new houses, where, apart from a temporary cause of smoking, arising from the large amount of moisture present in the recently-built chimney, it often arises from the door and windows shutting so closely as to prevent the entrance of air which usually enters a room by this channel. In this and other cases where no better arrangement can be adopted, it is a good plan to reduce the door slightly at the top; by which the air enters with a less perceptible draught than when it enters from under the door.

In all dwelling-rooms, and bed-rooms especially, a proper ventilation should be established, independently of doors and windows. For the exit of air, the fireplace and chimney, even when not in use, generally suffice, but are rendered more effective by the insertion of an "Arnott's valve" into the chimney, near the ceiling. The supply should come from openings placed wherever most convenient, communicating externally with the open air by "air-bricks" or gratings, and internally with fine wire gauze, or any other simple arrangement for preventing the entrance of air in masses.

Ventilation is especially requisite in sleeping-rooms, for reasons that will be specified in the following chapter. We need hardly say that no room that has not a fireplace should be used as a sleeping-room, and that the practice of stopping this up, is, to say the least, most injudicious.

Ventilation, as we have thus briefly glanced at, may be considered as an effective means of supplying us with one of the necessaries of life, and of protecting us from the influence of the ordinary aërial impurities of internal origin,—such as arise from our breath, and from lamps, candles, &c. Unfortunately, however, there are equally common, though less abundant, impurities in the air, against which ventilation affords no protection, because, being subtle and wide-spread, they pervade the entire atmosphere of a district, and are as likely to be encountered out of doors as in our dwellings.

At the same time, we must not, on this account, think lightly of ventilation, or suppose it to be less necessary; because, as already pointed out, the service performed by any arrangement for effecting a circulation of air through our dwelling-rooms, is of a constant and special character, altogether unconnected with the existence of such aërial impurities as we have above alluded to.

We ought now, perhaps, to narrate the more interesting characters and sources of the commoner sorts of impurities which tend to mar the efficiency of aërial food.

AERIAL IMPURITIES.

THE impurity we have so far only spoken of, viz. carbonic acid gas, although generally the most common and abundant of those found in the atmosphere of human dwellings, is yet, except, perhaps, in large quantities, the least harmless of the foreign substances which those of us who live in unwholesome districts, constantly receive into the system with the air we breathe.

The foreign ingredients occurring in the air, may conveniently be considered under three heads; viz.,—1st. Gaseous products which act injuriously, from the exercise of well-known chemical properties; such as coal-smoke, coal-gas, and the various products given off from certain manufactories. 2nd. Mechanical impurities; such as the various kinds of solid particles, or dust; also the more objectionable spores of fungi, animalcules, &c. 3rd. Emanations from putrescent animal and vegetable matter, which, although but little understood, are, probably, the worst of all aërial impurities.

To the first class properly belongs carbonic acid gas; but in consideration of its numerous and extensive sources, and the important part it plays in relation to our bodily economy, at all times and places, we have thought it advisable to describe separately. Another gas, closely related to carbonic acid, is carbonic oxide.

This gas also consists of carbon or charcoal, and oxygen, but in different proportions to those occurring in carbonic acid; it also differs from the latter gas in being inflammable. The blue flame often seen playing over a clear fire, consists of this gas, which is being converted into carbonic acid. Carbonic oxide is more injurious when inhaled than carbonic acid. It is chiefly to this gas, aided also by the latter, that the disastrous effects occasionally heard of, from burning charcoal-fires in closed rooms, are attributable. Of this character also is coal-gas, or the mixture of gases so extensively used for illuminating purposes under this name. The chief part of coal-gas consists of gases resembling carbonic oxide in their effects upon respiration: hence it is highly desirable that all gas-pipes, joints, &c. should be well constructed, so as to insure complete retention of the unconsumed gas; since, apart from the unpleasant smell of gas even in small portions, its inhalation for any length of time is decidedly injurious.

Another gas constituting one of the most unpleasant aërial impurities of this character, is sulphuretted hydrogen. This gas possesses a very peculiar and unpleasant odour, generally compared to the smell of rotten eggs,—an odour which, in fact, chiefly arises from small quantities of this gas generated from the putrefaction of the albumen of the egg. It consists of hydrogen and sulphur, or brimstone, both harmless enough in a separate state, but in this combination forming a very unpleasant-smelling as well as poisonous gas. It is found wherever animal matters putrefy, and is especially generated from cesspools, sewers, and ill-managed water-closets.

In an unmixed state, sulphuretted hydrogen is a powerful enemy to animal life, small animals immersed in it being killed instantaneously; and a horse has been killed by being left in an atmosphere containing only $\frac{1}{100}$th part of this gas. Men, whose occupation leads them to open sewers, &c., often suffer severely, and even fatally, from this gas; the effects of it on the human system being more dangerous, because more permanent, than in the case of the gases above mentioned. Even in a very dilute state, the odour of sulphuretted hydrogen is extremely disagreeable, while, in any appreciable quantity, it produces violent headache and oppression, especially in persons whose lungs are at all weak.

Another gas, somewhat related to the above, is sulphurous acid gas, which imparts the characteristic smell of burning brimstone. This gas, although, perhaps, less potent than the preceding, is yet exceedingly poisonous in an unmixed state, and is injurious, even in a minute quantity, when constantly inhaled. Sulphurous acid is one of the most objectionable ingredients of coal-smoke, in which it occurs, from the sulphur of coals being oxidized during combustion. Many of the objectionable qualities of the air of large cities may be traced to this gas.

That the atmosphere of towns and cities, where coal-smoke is abundant, contains appreciable quantities of this gas, is shown by the curious fact that the limestone of buildings, churches, &c., in these places is far more rapidly attacked by the weather, and corroded, than buildings constructed of the same stone elsewhere. The deposit or incrustation formed on stone under these circumstances, and which, by gradually deepening, leads to their comparatively early destruction, has been found to contain large quantities of sulphurous acid, combined with lime. These deposits also contain several other constituents of coal-smoke, with products arising therefrom; as ammonia and nitric acid.

Several other gases belonging to this class of aërial impurities, and more or less poisonous, are found in particular localities, especially adjacent to factories and chemical works, where particular processes are carried on; for instance, the peculiar irritating smell generally pervading the neighbourhood of vitriol-works (sulphuric acid), or the still more injurious fumes from soda-works (muriatic acid).

MECHANICAL IMPURITIES.

The next class of aërial impurities we have to notice are those we have called mechanical impurities; such as soot, dust, &c.

These bodies differ entirely in their physical characters from the foregoing, and are only miscible with air when more or less finely divided.

We are inclined to think that this description of impurities in the air constitutes a more serious source of injury than is commonly imagined. Not that we at all believe that an occasional exposure to a dusty atmosphere is productive of harm, but that an atmosphère loaded with solid particles in suspension is perhaps the one we are least able to bear exposure to, for any length of time, without injury. Of course much depends on the nature of the solid in question, whether it acts purely mechanically, as we may imagine the fine particles thrown up from a dusty road, &c., would act; or if it also acts chemically, or perhaps physiologically, as in the case of the dust of chemists' drugs, &c., known to exert particular effects when received into the system.

But even supposing that no more than a mechanical effect results from the inhalation of such impurities, there is reason for believing that they exert no small influence on the health of those who are exposed to them. We would even go so far as to say that the superiority of the open air, compared to that found in-doors, is mainly due to the comparative freedom from these kinds of impurities in the former, and that the unhealthiness of in-door and sedentary employments is quite as much owing to the effects of dust, as to other generally more regarded aërial impurities.

The truth of the foregoing remarks will perhaps be admitted, when it is recollected that Nature has made but little provision for protecting our lungs from the direct effects of any impurities taken in the breath; since there is an uninterrupted passage from the mouth to the remotest recesses of the lungs, and the extremely delicate structure of these organs is undoubtedly as susceptible to mechanical injury from the comparatively large particles of any solid impurities in the air, as the entire system is from any poisonous effects of the infinitely smaller particles of gases which enter the blood through this channel.

The only natural provision existing against injury from this source is the mucous secretion of the air-passages. This, by a constant movement upwards, carries with it any foreign material of this character accidentally received in the breath; but as this is the only channel by which solid impurities of any kind, that have entered the lungs, can possibly be removed, it is easy to understand that this provision, being intended only for occasional action, may be overtaxed, and become inadequate to perform its office when the work imposed on it is of a severe and sustained character.

Cotton-spinners, chimney-sweeps, dry-grinders of cutlery, &c., are known to be terribly subject to disease of the lungs, clearly traceable to injury of this description. Moreover, the short duration of life amongst all persons habitually exposed to a dusty atmosphere, sufficiently testifies to the injurious action of this kind of aërial impurity.

The extent of injury likely to be incurred from this source, depends, however, much upon the nature of the material dealt with.

Excepting, perhaps, the dust of drugs, chemicals, &c., known to have a poisonous action on the system, the worst kinds of solid impurities that can be received with the breath, are those recently separated from any very hard and brittle material, the finer particles of which, though perhaps invisible to the naked eye, possess the same angular character noticeable in those which are larger. Thus it happens that grinders of cutlery, gas-stokers (the men who remove the coke from the retorts in gas-works and refill them with coal), and other occupations of this description, are painfully remarkable for the shortness of life in those who follow them.

The dust of broken glass is of this character; and we believe that the chief reason why the extremely beautiful fabrics woven of glass thread, and which, some years ago, promised even to compete with silk, were disused, was on account of the injury they gave rise to in those who wore or worked at them. At all events, it is a well-authenticated fact, that several dressmakers were attacked with serious irritation of the air-passages of the lungs, from having worked at a robe of the material desired by a popular actress. It seems highly probable that a studied exclusion of this kind of impurity from the air supplied to invalids suffering from diseases of the lungs, would be attended with benefit.

The impurities of this description commonly met with in properly-managed dwellings, are not likely to reach any injurious extent; but the amount of dust often thrown up from carpets, matting, &c., where much treading goes on, often reaches a disagreeable, and even injurious extent. This is especially the case in some places of public resort, where carpets or matting, cushions, &c., are too freely used; in many such places this evil prevails to a very objectionable extent, and is, undoubtedly, the most active cause of the bronchial affections often suffered by those who habitually exert the voice in such places. All such sources of dust in rooms, carriages, &c., should be avoided as far as possible, and should never be tolerated, unless periodically and *thoroughly* cleaned, an operation, however, which the faulty arrangements of these so-called accessories to comfort, seldom admit of.

We ought here, perhaps, to mention a matter brought to notice from time to time, which has, to say the least, caused much uneasiness amongst persons generally. We allude to the presence of arsenic and its compounds in paper-hangings, and the probability of these poisons being carried into our system in the shape of dust detached from the walls of rooms so decorated.

Although the dangers likely to arise from this source have, no doubt, often been exaggerated, and, on the other hand, more frequently treated with contemptuous ridicule, it is certainly true that the majority of green wall-paper contains large quantities of highly-poisonous combinations of arsenic; and that such combinations are likely to become detached from the paper and pervade the room as dust, cannot be doubted by any one who takes the trouble to examine such paper.

The use of green arsenical pigments is prevalent in the manufacture of all kinds of wall-papers; those called "flock" papers being the most objectionable, while the glazed papers are comparatively harmless. These colouring matters are also found, though less commonly, in papers of a cheaper description. In a paper I lately examined, the pattern of which was made up of different shades of green, the quantity of arsenic present was remarkably great, and in a highly-objectionable form, as the green colouring matter was freely detached by contact with the finger. I may further add, that the man engaged in hanging this paper suffered indisposition for some days, and remarked, as a circumstance unaccountable to him, that the same result had followed its performance on other occasions.

To say the least, it is exceedingly injudicious to place such potent poisons in such close proximity to ourselves, as we do in using these pigments for paper-hangings; as, however remote the chances of injury may be under ordinary circumstances, harm may come of it in unlooked-for ways.

The incautious, or even common use, of powerful poisons like arsenic, for instance, for poisoning vermin, or in manufactures, &c., ought to be discountenanced as much as possible; since the danger to human life, but especially health, is at all times great; and, moreover, in nine cases out of ten, some harmless substitute might be found at the expense of a little trouble in looking for it. This has been effected in numerous instances. To mention one in connection with the poison above spoken of. Arsenic was formerly used in making composite candles, its presence being believed necessary at a certain stage of the manufacture: the same result is, however, now obtained by mechanical means.

The particles of soot or "blacks," so unpleasantly abundant in the air where coal is burned, are probably the least objectionable kinds of solid impurities as regards health (though not perhaps to housewives). This is because the carbon of which they consist, and in the condition found in them, is devoid of all chemical qualities, and also of the most objectionable mechanical ones. It has even been suggested, with a strong probability of truth, that the multitude of blacks floating in the air of close neighbourhoods tend to mitigate the evils arising from more objectionable aërial impurities. Their effect in this way may be inferred from the fact of carbon, in a porous condition, being a powerful absorbent, and oxidizer of offensive exhalations, such as we are now about to speak of.

Another group of aërial impurities remain to be noticed; viz., those emanating from putrefying animal and vegetable matter.

ORGANIC IMPURITIES.

In addition to the more abundant products of the Decay and Putrefaction of animal and vegetable matter, which, as already stated, consist of carbonic acid gas, water, and ammonia, there are generally produced, in much smaller quantity, certain products, varying with the circumstances under which these processes take place. These latter products give rise to the more or less offensive odours generally perceptible where these processes of destruction proceed. They do not always, however, make their presence known to us in this manner; many of the worst kinds possess no striking smell, and hence assail us at a great advantage.

To this class of compounds belong the fetid emanations from stagnant drains, cesspools, stagnant water, and swamps, as well as the more subtle agents which convey epidemic fever, &c., and the indefinite poisons of hot climates known as malaria. We may certainly regard these impurities of the air as the most potent, though commonly the least abundant and least active.

Even the more abundant of these products are but little understood, while of the majority, nothing definite is known. They can at present only be defined as intermediate products, arising from the incomplete oxidation of organic matter. The formation of such products may be conceived from the familiar example furnished on the blowing out of a candle.

The unpleasant-smelling compounds, which immediately display themselves when the flame is blown off, have been generated all the time the candle has been burning, but by the combustion they have been converted into lower or simpler combinations, which, having no smell, pass off into the room unnoticed. Thus the consumption of the tallow is effected not by any direct change into the ultimate products of combustion, but by the formation of a series of intermediate products, which generally possess a more or less unpleasant odour.

It is easy to conceive that compounds containing nitrogen, phosphorus, and sulphur, in addition to the constituents of tallow, will give off far more complicated products when they suffer decomposition than a comparatively simple compound like tallow. In this way we account for the stronger and more offensive odours given off from animal, or rather from nitrogenized matter, during its decay.

Many products of this character are apt to become powerful and subtle poisons to human life and health, although the circumstances which lead to their action in this manner are but little known to us.

It is believed, however, that such substances, when conveyed to the blood through the breath, act upon it in a manner analogous to a ferment, and that this action can only take place when the blood happens to be predisposed to it, or rather, when its vital power of resistance is from some cause materially weakened.

That a minute quantity of matter in a peculiar condition shall be able to communicate a particular change to a large quantity of material with which it is brought in contact, is evident from a number of well-known processes; as, for instance, the rapid conversion of sugar into alcohol when a small quantity of yeast is added to a liquid containing sugar. Again, the extraordinary alteration rapidly effected in milk by the addition of a small portion of rennet, is another example of the power of this important class of bodies. Although such influences are less likely to assail living structures, yet, if we recollect the complex character of our blood, the number of its constituents, and the dissimilarity of these, we can readily conceive that a very slight influence exerted at some vulnerable point would be sufficient to derange the delicate adjustment indispensable for the maintenance of health.

This is the most rational explanation that has been given of the effects of epidemic and contagious diseases.

Were it not for the fact that the tendency to health and prolongation of life is stronger in us than we have any reason to expect, or can at all account for on physiological grounds, disease of this kind would be much more frequent than it is, as its sources are extremely numerous. But it is only when they assume a very potent form, or when they assail us at peculiar advantage, as when, from neglect of general health, the system is already overstrained to preserve its equilibrium, that we commonly fall beneath their attacks.

Poisonous substances of this character seldom enter the system through the stomach and digestive organs; since it is known that the stomach possesses considerable power of checking and rendering harmless organic compounds in an incipient state of decay; a provision, as already noticed, which often protects us from injury that would otherwise arise from unwholesome food, especially meat that we may have unconsciously partaken of.

But no such provision exists in connection with the respiratory organs, through which such impurities, if present in the air, can at any time find entrance into our blood.

The complaints periodically prevalent in the neighbourhood of marshes and badly-drained districts are, without doubt, induced by products of the above character, which may be harmless to many persons, but absolute poisons to others, who happen to be susceptible to their influence.

Nature has taken great pains, so to speak, to diminish as much as possible the liberation of poisonous emanations from putrefying animal and vegetable matter, by making it the temporary habitation of certain classes of the lowest grade of animal life, by whose labours the process of destruction is greatly accelerated, and at the same time freed, to a great extent, from objectionable emanations. Thus the stagnant water of ponds, ditches, &c., becomes, at certain seasons, when it is most likely to become objectionable, the abode of myriads of animalcules (*Infusoria*), which greedily eat up everything corruptible, and thus prevent its polluting the air.

If, however, the conditions necessary for the existence of these creatures are interrupted, their good office ceases, and dangerous results are much more likely to follow. Thus it is well known that marshes and swamps, &c., notorious in the way above spoken of, are never so dangerous as when, from protracted dry weather, they become partially dried up, a result in part traceable to the destruction of these useful agents.

Other sources of aërial impurities of the kind now under consideration, are the over-crowded and ill-conditioned parts of London and other large towns, where human beings exist in a state more or less opposed to the requirements of nature. We allude to those ill-built and badly-situated lanes and alleys unhappily still too common in most large towns, where squalid poverty huddles away, and crime seeks a refuge.

In these places every kind of abomination accumulates and putrefies, even though ostensibly cleaned out from time to time; since the houses themselves,—the walls and woodwork,—not to speak of the furniture and inhabitants,—are saturated with that corrupt matter, which, at certain seasons, in the summer time, is likely to give birth to some of those formidable classes of impurities above spoken of, which, once generated, are likely to spread far and wide.

That these places need not be, is evident from the fact that the inhabitants of such wretched abodes, though enduring every kind of privation in decency and comfort, often pay a great deal more rent than would be amply remunerative for wholesome dwellings. The highly meritorious attempts which have already been made for affording reasonable accommodation for the lowest classes of society have, we believe, yielded not only a vast amount of good, but also (what is generally more significant) a good interest of money: hence we may fairly hope that, ere long, benevolence will be more extended in this direction.

In connection with our present subject, we may add that a source of aërial impurity, somewhat allied to the above, is the dirt and other impurities which accumulate in places out of the reach of brooms and scrubbing-brushes, in cellars, lofts, and unused places. Not only bedding and furniture, but even the woodwork and walls of rooms, become in time impregnated with objectionable matter, even under the most wholesome and refined phases of domestic life.

It is this circumstance which necessitates the periodical *thorough* cleaning and airing of everything belonging to or forming part of inhabited or uninhabited chambers, &c., which forms so important a department in the business of an intelligent housewife.

The freshest air we can get, in conjunction with sunshine, are the means nature has placed at our disposal, to aid the efforts of labour, patience, and perseverance in the performance of this, as well as all similar kinds of domestic labour. These invaluable natural agents will do much towards preventing any serious results arising from the neglect of these duties of domestic life; but the mode of doing these things in a manner to satisfy a refined taste, demands a much greater amount of intelligence and attention than is commonly supposed necessary.

The principles of cleaning, that is, of cleansing generally, are, in fact, dependent on laws which only refined quantitative science elucidates; but though these principles are intuitively perceived by intelligent persons, they are sadly neglected or altogether unknown to a vast number of persons, especially in the lower ranks of life, in whose homes such knowledge is most calculated to be of service. We are of opinion that if the art of cleaning, in the fullest sense of the term, were made a department in female education, especially in schools of the lower grades, much good would result.

No doubt, the matters above spoken of will be thought by some persons too trivial for serious consideration ; but the least reflection will show that they influence, to no small extent, the comfort, health, and happiness of persons generally, especially of invalids, and persons who spend much of their time in-doors.* Moreover, a prolonged and aggravated neglect of these matters, aided, perhaps, by various unfavourable conditions in nature, are, without doubt, the immediate causes of a large class of diseases, especially those of an epidemic character already referred to. The horrible scourges of plague, &c., even in this country, in times past, and the milder visitations of cholera, typhus, and other fevers, &c., of the present time, are at least fostered, if not generated, in the corruption mankind, in their misery, ignorance, or negligence, are capable of giving rise to.

We may here, perhaps, venture to allude to the custom, now happily becoming extinct, of intramural interments. It is difficult to conceive how this custom of burial in churches, probably originating in superstition, could have become so common amongst us, seeing that it is opposed to all good sense and delicacy, as well as to all natural laws.

All right-minded persons have an instinctive perception of the truth so often told in Scripture, and verified in the clearest manner by chemistry, that ourselves, so far as regards the material portion of us, consist simply of materials derived from the earth, and which are, therefore, not exempt from the laws to which all earthly materials have been made subject.

Hence, the returning of our bodies to the earth after death, is a natural and proper proceeding, in strict accordance with all natural laws; the extraordinary properties of earth or soil (presently to be noticed) insuring the passing away of our remains in a manner devoid of all danger or annoyance to the living. But how this beautiful custom could have been so perverted as to admit of the attempted preservation of the dead, out of the ground, in our churches, and in the immediate proximity of the congregations thereof, is extremely difficult of comprehension.

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* Since writing the above, I have been much gratified by seeing this matter more ably treated in Miss Nightingale's admirable "Notes on Nursing."

By this pernicious custom, places of worship are sometimes rendered wholly unfit for human occupation; since the emanations from this source (which *must* escape sooner or later, whatever precautions be taken to prevent them) are amongst the most repulsive, if not the most detrimental, of those above mentioned. This state of things is especially the case in the City churches of London (to which these remarks more particularly apply), as shown by recent reports of Dr. Letheby, upon the condition of the City churches in this respect.

In concluding our description of aërial impurities, we may add that the foul odours characteristic of certain trades which deal with corrupt animal matter, such as bone-boilers, glue-makers, fell-mongers, &c., belong to this latter class of aërial impurities.

Another prolific source, especially well known to Londoners, is the once beautiful river Thames, now constituting the worst-conditioned common sewer of the largest city of the world.

It is to be sincerely hoped that the efforts now being made for the alteration of the present state of the Thames (especially the now seriously entertained project of embankment, which seems the only hope of a better state of things) will meet with success, as this river, in its present state, is likely to become, in hot seasons, a fearful source of aërial impurity, and even a possible source of pestilence.

DISINFECTANTS.

DISINFECTANTS afford one of the best means at our disposal for counteracting the ill effects of certain kinds of aërial impurities, particularly those of organic origin, or of the kind last spoken of. Disinfectants must not be confounded with what are merely fumigants, a term we use to express mixtures which, by burning, or otherwise, give off odoriferous vapours. Although many of these latter substances act as weak disinfectants, they more frequently merely conceal any objectionable odour they may be used to get rid of. Disinfectants, however, act chemically, and sometimes, also, mechanically, upon the compounds they are employed against, and by altering their nature, render them harmless; moreover, disinfectants of the more active kind are often, for the time being, as objectionable as the evils they are intended to remedy, and therefore require to be used with caution.

The best instance of this is afforded by chlorine gas, which, although a dangerous poison in an unmixed state, is yet, perhaps, the most valuable disinfectant in use. In an unmixed state, chlorine is a heavy, greenish-coloured gas, exceedingly poisonous; a property, however, which it seems to lose, even in degree, when very much diluted.

Chlorine is the basis of all disinfectants commonly used; such as chloride of lime, or bleaching-powder, chloride of zinc, chloride of iron, &c. All these substances owe their powers of destroying bad smells, or infectious matter, to the chlorine they contain, and which is slowly given off on exposure to the air, or on mixing with various substances. Chlorine itself is also used dissolved in water, and is frequently applied directly to the same purposes; but can only be safely used by those who have some knowledge of its qualities.

Chlorine is a most powerful destroyer of organic compounds; animal and vegetable products of every sort are sooner or later disposed of by exposure to this agent: hence, all offensive products, against which disinfectants are used, are instantly destroyed by contact with chlorine, which breaks them up, so to speak, and converts them into comparatively harmless products. This action of chlorine upon bad-smelling or poisonous substances, may be understood by witnessing its analogous action on all colouring matters of animal or vegetable origin, — a property upon which depends its extensive application in the arts and manufactures.

If a little ink, infusion of red cabbage, or any flowers (especially blue ones), are immersed in water, with a little chloride of lime, the colour gradually disappears, owing to their elements having been disarranged by the powerful action of chlorine.

Chloride of lime, or bleaching-powder, is the form of chlorine most employed for disinfecting purposes; since it offers a ready means of applying any desirable quantity of chlorine to purposes for which it may be necessary. By mere exposure to the air, this substance gives off small quantities of chlorine, sufficient, in most cases, for the purposes of disinfection. When a stronger action is desired, it may be obtained by adding any dilute acid, as vinegar, to the chloride of lime, which may thus be made to give off almost any quantity of the gas. In using this substance, it must not be forgotten that too much of the gas (indicated by its unpleasant taste and smell) must be avoided, although any slight excess, as above noticed, is not very injurious. If too much should have been unintentionally liberated, the best remedy is to sprinkle alcohol, or spirits of wine, about the chamber. The best mode of applying this and similar disinfectants, is to mix up some of the moist powder with water, and expose it in plates, or other shallow vessels, in the place desired to be purified. For the removal of bad smells in drains, water-closets, &c., the chloride thus liquified may be applied by pouring it where desired to act.

Another excellent disinfectant, less commonly used than the above, is nitric acid, or aqua fortis. This compound (in the shape of vapour, or otherwise) acts upon organic matter less powerfully than chlorine, but for many purposes is a much safer disinfectant.

If strong nitric acid can be procured (known by its fuming on exposure to the air), it is sufficient merely to expose some of it in a shallow vessel, when its fumes gradually rise into the air and effect the purpose desired. If it can be got only in a dilute state (that is, as a colourless liquid, that does not fume), the same end may be attained by pouring some of it on a hot brick or stone, in the chamber intended to be fumigated.

The milder kinds of disinfectants are lime, charcoal, earth, &c. These substances can only act as disinfectants when brought in contact with the sources of the objectionable products; as the physical condition of these solids prevents their following aërial impurities when once liberated, hence, their action is necessarily limited. Nevertheless, these substances, the two latter especially, are useful disinfectants, inasmuch as they supply us with an excellent means of preventing the liberation of offensive exhalations from animal and vegetable substances during their decay.

It need, perhaps, hardly be said that lime, when used for this purpose, must be in a caustic or recently burned state. It is best applied in a semifluid state, obtained by mixing with water. Lime, like all alkaline bodies, shows a great tendency to corrode and destroy organic matter of every kind,—a property upon which its use, in this and several other ways, depends. In the present case its value also depends on its hastening the destruction of organic matter, in such a manner as to prevent, in a great measure, the liberation of intermediate products, which, as we have seen, are the products we most wish to avoid.

One of the most valuable applications of lime is in the shape of whitewash. The walls of all places, where an ornamental covering is unnecessary, are best covered with whitewash, which, well prepared and laid on, constitutes one of the best coverings for walls. All cellars and underground places especially, by being periodically whitewashed, are purified and rendered wholesome; a result due in part to the caustic action of the lime, which destroys the minute fungous growths, always found in such places, and which give rise to peculiar mouldy smells, generally perceptible there. It also acts beneficially by greatly increasing the amount of light admitted to these places, which, as before hinted, is a powerful purifying agent.

Earth, that is, dry soil or mould, &c., is also one of the best and cheapest disinfectants for preventing the liberation of unwholesome products during the decay of organic matter. Dung-heaps, night-soil, &c., may be rendered thoroughly inoffensive by even a thin covering of earth. Of solid disinfectants, perhaps the most effective is charcoal-dust, which absorbs in an extraordinary manner most of the objectionable products arising from putrefaction and decay. By recent experiments it has been shown that masses of animal matter, such as the carcasses of animals, may be prevented from giving off any unpleasant-smelling products during their decay, by a slight covering, on all sides, of charcoal-dust.

Charcoal is often thought to be an antiseptic. This is hardly true, as, although it may be used advantageously to preserve, for a short time, meat, fish, &c., or to sweeten it when tainted, it does not seem to retard to any extent the natural powers of putrefaction, but, by absorbing the products arising therefrom, prevents their further action on the inclosed substance. Thus, in the experiments above noticed, decay proceeded as under ordinary circumstances, but the intermediate products liberated during the process, in their passage through the charcoal, are completely oxidized, and converted into the ultimate products of decay; viz., carbonic acid, water, and ammonia, which, for the most part, are odourless and comparatively harmless. This useful property of charcoal is ascribed to its extreme porosity, in virtue of which it absorbs and condenses gases within its pores, so that compounds capable of oxidation, are brought in contact with the free oxygen, also present (derived from the air), and by combination with it are converted into simpler and inert products. This curious property is possessed in different degrees by many other porous solids: the action of earth, in the way above noticed, depends on a similar property.

As charcoal can only exert this property upon objectionable gases, when in actual contact with them, it can be of little or no avail when merely exposed in a room, as is sometimes done, with the view of purifying the air: hence, charcoal can in very few instances be used in place of the more powerful disinfectants before spoken of.

CHAPTER V.

CHEMISTRY OF OURSELVES.

Having now become acquainted with the composition and more important properties of the chief kinds of materials required for our sustenance, it remains for us to extend our observations to the progress of these materials after they have been taken as food, in order that we may understand their several uses, and how, by their united action, they contribute to our health and strength.

Before we can do this, it is necessary that we know something of the chemical nature of our bodies, which food, &c., is intended to nourish. We therefore purpose, first, to describe, in as simple a manner as possible, the composition of the human body, *i. e.*, the nature of the materials composing it, their relative quantities, and the functions and offices they are severally most associated with.

In doing this, we shall avoid, as much as possible, all description of the structure and action of the various organs of the human body, dealing only with the materials they operate upon; since these matters belong to the sciences of anatomy and physiology, upon whose domains we have no intention of encroaching.

Neither shall we make the slightest attempt to inquire into the more mysterious departments of our nature, such as, for instance, the "vital force." This term we understand to mean that marvellous power of selection by which the comparatively crude materials of food, &c., are duly sorted and ranged in the peculiar *organic* form necessary before they can become part of our structure. This power, variously modified and of different degrees, is seated in every part of our system, and by it each organ prepares, from a supply of materials common to all, those particular structures it requires. Thus, a bone and a muscle (flesh) are each nourished from the same source (the blood), though the materials severally composing these organs, as well as their structure, are wholly different. The vessels whose office it is to provide for the support of the bone, select from the common source (the blood) those materials of which bone is composed, and further give to them the organized form of bony structure. The corresponding vessels of muscle or flesh respectively do the same.

But the presence of an inherent power of this kind, call it by what name we will, is made more apparent by the fact, that the materials chosen by several organs are often alike, chemically, *i. e.*, in quality and quantity; yet their structure and physiological uses differ as much as in the two former cases. For instance, the skin, the tendons or leaders, and even the nails, and a great many of the internal membranes, are composed of the same materials (which, in an unorganized state, we call gelatine), although the physiological characters of these organs are extremely varied.

Thus, we are compelled to recognize in all living beings a process or processes altogether different from what we call chemical action, or any other action of an inorganic source. But upon this, or other matters of the kind, we have no intention of entering; since the profoundest science teaches us little respecting them. It is true, physiology reveals the beautiful mechanism with which Nature works in this way, and chemistry shows us the materials she uses; but of the processes themselves, that is, how the organic structure is produced, we are entirely ignorant. Most of us are content to accept them as some of the profoundest mysteries of our being, or, rather, as manifestations of the Creator's will.

Although a knowledge of physiology greatly aids our conception of the chemical processes proceeding in the human frame, yet the absence of such knowledge by no means prevents our deriving entertainment or instruction from the following general remarks concerning the relations of chemistry with ourselves.

While, as we have said, very little is known of the fundamental causes upon which the action of the various organs of our system depends, we yet know a great deal of the conditions necessary for their proper action, and of the circumstances which interfere with them. This knowledge belongs, in part, to medical science; but a good deal of it should be possessed by every one, because it relates to matters of daily occurrence, which may influence, for good or evil, the happiness and well-being of ourselves and neighbours.

For instance, most of us are aware how much our health and comfort are influenced by the quantity, quality, and mode of receiving those materials commonly included under the general title of food. Solid and liquid food are allowed to be more potent in this respect than the material supplied by the atmosphere; yet, as we have partly seen, even the kind of air we breathe influences, to no small extent, our general health.

As we can generally choose the kind of solid and liquid food we take, and can mix it and prepare it in any way we please, we may, if inclined to accept the truths taught by science in this respect, derive considerable aid from the knowledge of the properties and functions of food. Again, though the quality of the air we breathe is generally less under control, yet the condition in which we receive this commodity may, under almost any circumstances, be made to approach nearer to purity, if we understand the value of good air, and take reasonable care to preserve it from unnecessary sources of contamination.

In the following pages we shall consider the connection of the constituents of food of each kind spoken of in the preceding chapters, one with another, and with our general well-being.

COMPOSITION OF THE HUMAN BODY.

The surprise which was probably felt on learning the large proportion of water in certain common sorts of food, will perhaps be again excited, when we say that a proportion of water almost as large exists in our bodies. Water, in short, pervades to an extraordinary extent the entire organic world. From the lowest creatures amongst animated beings up to man himself, water forms, as a rule, by far the larger portion of their bulk and weight.

The quantity of water in a person of moderate size and weight is about 101 lbs., or about 10 gallons.

It must not be supposed that this quantity of water is contained in our system in masses; such as a cask, or bag, or a pile of these vessels would contain it: it is some erroneous impression of this kind which excites incredulity of this fact in the minds of unreflecting persons. This large quantity of water present in us is called water of constitution; that is to say, it forms a part of, and, to a great extent, confers identity upon those structures in which it occurs.

A better idea of the kind of office water performs in this respect, may, perhaps, be gathered by a simile borrowed from the vegetable kingdom: a leaf, for instance, can only be a leaf in relation to its parent plant, so long as it contains the large proportion of water always contained in it in a living state; the water is, in fact, a definite part of its essential juices.

The water of our bodies exists, there, in an analogous form; in the blood, for instance, it occurs in an invariable proportion; in the flesh and muscles again, and the fluids pervading them, water occurs in definite quantities; without which the characteristic functions of these structures could not proceed.

Next to water, the most abundant constituent of our bodies is carbon, or charcoal. This substance, and hydrogen, nitrogen, and oxygen, are, exclusive of water, the elements of which by far the greater part of the entire fabric is composed.

Thus the well-known components of the body, already referred to, viz., muscle or flesh, consist, after deducting the water and mineral matter, of—

	FLESH. (Fibrine of flesh.)
Carbon	54
Nitrogen	16
Hydrogen	7
Oxygen	23
	100

Again, skin, membrane, nails, &c., consist of (exclusive of small quantities of mineral matter)—

Carbon	51
Nitrogen	18
Hydrogen	7
Oxygen	24
	100

All internal and less well-known parts of the frame contain proportionately large quantities of these organic elements, as they are sometimes called. It should also be mentioned, that water also consists of two of these elements, oxygen and hydrogen; but as, in the shape of water, these elements take no share in the organic structure otherwise than as water, we have thought it advisable to speak of water as a separate material.

From what has been said in a previous chapter, of the nature of these elements, it will be seen that all these solid parts of our bodies consist of materials which, for the most part, are in their normal state gases.

We must next proceed to speak of certain less abundant but equally important constituents of the body—the so-called inorganic portion—the mineral substances named in the foregoing chapters.

Before doing so, perhaps it will be well here to introduce, in a tabular form, the constituents of a man, and also their approximate quantities.

APPROXIMATE* COMPOSITION OF A MAN WEIGHING TEN STONE, OR 140 POUNDS:—

Water	101
Dry substance	39

Dry substance consists of—

	lbs.			lbs.	oz.	
Albumen, globulin, and fibrine (of flesh)	8½	=	Carbon	14	9½	
Gelatine and fibrine (of blood)	13		Hydrogen	5	0	(=945 cubic feet)
Fatty substances	7½		Oxygen	5	12	(= 67 „)
Mineral matter	10		Nitrogen	3	12	(= 49 „)
	39			grains.		
			Phosphorus	250		in organic combination.
			Sulphur	700		

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* The above approximation has been arrived at by calculations,

The mineral matter consists of—

	lbs.	oz.	grs.	
Phosphate of lime	8	0	0	From bones.
Phosphate of magnesia	0	5	37	
Carbonate of lime	1	0	0	
Fluoride of caleine	0	0	20	
	9	5	57	

	Grains (437½ grs. = 1 oz. avoir.)	
Phosphate of lime	353	From other parts.
Phosphate of magnesia	218	
Phosphate of potash	2149	
Phosphate of soda	610	
Chloride of sodium	710	
Chloride of potassium	473	
Oxide of iron	106	
Carbonate of soda	104	
Sulphate of potash	27	
	4750 = 10 oz. 380 grains.	

MINERAL ELEMENTS OF THE BODY.

As we have already described the more interesting properties of the materials referred to in the foregoing tables, as inorganic or mineral elements, and the general points of difference between them and the organic elements, we may here pass over all notice of their individual characters, and shall here speak of them only in relation to the positions they respectively occupy in the human frame.

Although we can hardly be allowed to speak of the comparative importance of a group of elements, all of which are indispensable in the system, an order of precedence, based on the extent of their connection with the different vital phenomena, may perhaps be permitted for the sake of convenience.

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upon the assumption that the human body contains 72 per cent. of water (founded on the proportions existing in animals), and that the dry substances consist of bones, 14 lbs.; blood, 3·66 lbs. (=18 lbs. in natural state); flesh, 7 lbs.; and membranes, skin, nerves, &c., 7¼ lbs. The proportions of bones and blood, and the composition of these, and also that of flesh, have been calculated from the composition given in Leghman's "Physiological Chemistry."

In following this order, we shall, without hesitation, place first on the list *phosphorus*, and its chief oxide *phosphoric acid;* since these substances, though by no means very abundant in the majority of structures in which they occur, yet seem to be connected more closely than any others with the economy of living structures.

We find phosphoric acid in nearly every part of the frame, but in several different combinations, and performing, apparently, as many different offices. For instance, in the blood we find several salts of phosphoric acid; viz., phosphate of soda, phosphate of potash, and phosphate of lime. These salts are all essential constituents of this most vital fluid, being never absent from it. In the fluids pervading the muscles (the sources of strength) there occur similar salts of phosphoric acid in comparatively large quantities. Each of these salts seems to have a special purpose allotted to it, in which the phosphoric acid takes the principal share. Again, in the albumen of the blood (perhaps the most essential constituent of this fluid, for the reasons we shall presently point out), and also in the brain and nerves, phosphorus itself (the basis or radical of phosphoric acid) occurs in very intricate organic combinations; in the two latter cases also associated with phosphoric acid as well.

The largest quantity of phosphoric acid, however, exists in the bones, in the shape of phosphate of lime and magnesia: its office in this way, however, seems to be only mechanical, and subordinate to the foregoing.

It is this substance which confers upon our bones their remarkably permanent character, in virtue of which they are always the last parts of our frame to return to their mother earth. It is also the remarkably large proportion of this mineral substance in the bones (about two-thirds of their weight) which endows them with the rigidity and strength necessary, not only for supporting the weight of our body and limbs, but also to direct the power of the muscles during exertion.

Another mineral substance, which appears to exert a marked influence on our health, is iron, or rather oxide of iron. The quantity of this compound is, however, but small; very much smaller than the substances above noticed. The old-fashioned saying that there is enough iron in twenty men to make a sword is entirely false. Nevertheless, the small quantity of iron in our body although so small, as seen in the above table (about 74 grains), no doubt exercises a very important function in regard to our physical condition. It exists almost exclusively in the blood, and in the most vital portion of the blood, viz., its red corpuscles. All of our readers may not, perhaps, be aware that the red colour of blood is due to a multitude of red globules, or rather discs (perceptible under a good microscope), which float in a clear liquid, as little flat bodies, which constantly exhibit a tendency to group together in rows, like overturned piles of money. The fact of iron, judiciously administered, having the effect of increasing the red blood globules, in diseases where they have become deficient, further testifies to the importance of iron in the human frame.

Next come lime, potash, soda, and magnesia; compounds, it will be remembered, belonging to the group of Bases. Lime occurs in large quantity in the bones, where, with phosphoric acid, in the shape of phosphate of lime, it forms the greater part of the large quantity of mineral matter, above noticed, as belonging to these structures. Lime also occurs in the bones in smaller quantity, as carbonate of lime. Magnesia occupies for the most part the same situation. The blood also contains small quantities of these salts.

Potash occurs chiefly as phosphate of potash, and, more or less, in almost every part of the body, but especially in the flesh or muscles, where it seems to be intimately associated with their action and nutrition.

Soda occurs also as phosphate of soda, chloride of sodium, and in small quantities as carbonate of soda. These salts of soda chiefly exist in the blood.

Chloride of sodium, or common salt, is an article of considerable importance in our system. It occurs, as above stated, in the blood, of which it forms an essential constituent. We may safely infer this from the fact of its occurring in a constant proportion.

This fact furnishes, we think, the best possible evidence in favour of the custom of eating salt with our food. Athough persons have from time to time attempted to prove that salt is injurious to mankind, and is the source of all kinds of derangement and disease, and ought therefore not to be taken; yet, we think, that the fact of its occurring in unvarying proportions in the most vital fluid of our body (viz. blood), and also the fact of sea-water and sea-air (both highly impregnated with salt,—the latter only of course comparatively) being notoriously beneficial to human health, are sufficient to assure us, not only of the harmlessness, but also of the usefulness of salt as an habitual addition to our food.

The objections sometimes raised against salt, on the grounds of its producing the terrible diseases which often display themselves in persons who have lived for a length of time on salt food, are, as before noticed, without foundation; since, although provisions of this kind may be less digestible, and therefore less wholesome than fresh ones, yet the derangement in question is known to be caused by a deficiency of mineral salts (chiefly phosphate of potash), which are lost in the process of salting.

It will be noticed from the foregoing table, and the above remarks thereon, that the materials composing our bodies are identical with those we had formerly become acquainted with as constituents of food. We need, therefore, scarcely add, that but one set of elements compose ourselves, the inferior animals, and even plants; in short, the entire organic world. We may also call to memory the fact of these materials having been all, in the first instance, derived from the earth; *i. e.*, the inorganic departments of the earth; viz., air, water, and soil. Thus, we perceive how clearly science verifies the truth so often taught in Scripture, that we are but dust of the earth!

Men contemplate these facts differently: some dismiss the thoughts they engender with aversion; others take them to be in no way unpleasant, but rather gratifying than otherwise, inasmuch as they help to exhibit the superior regard of the Divine Being for mankind, as compared with the inferior creatures. The characteristic difference in form, intelligence, &c., being thus the result of a superior handiwork, or modelling (if the expression may be allowed); since the materials employed in all cases are alike.

PURPOSES PERFORMED BY SOLID FOOD.

THE fact of our getting thin and losing weight if we undergo, for any length of time, more than ordinary fatigue of mind or body, furnishes familiar evidence of the truth taught by physiology, and supported by chemistry, that our bodies are continually suffering loss by wear and tear.

Perhaps it would be more correct to say that the constituents of our bodies are constantly undergoing a more or less rapid change or replacement; since this change only assumes the character of a loss when the quantity of material worn away is greater than that provided for its replacement,—a condition incompatible with good health. Again, the equally common circumstance of our getting stouter, stronger, and heavier on good living, when agreeably occupied with enough, but no excess, of bodily or mental exertion, furnishes additional evidence, if any were needed, that the materials composing our body are undergoing an incessant change or replacement, the speed of which varies with the circumstances in which we are placed.

The object of this interchange of the materials composing the body, we shall next proceed to explain, and in doing so we shall discover the best reason why we continually consume new materials of each kind of food, spoken of under the general title of food.

LOSS OF SUBSTANCE BY BREATHING.

EVERY breath of air we expire takes with it materials which were but lately a part of ourselves. The air we inhale consists, as we have seen, of oxygen and nitrogen gases, with traces only of carbonic acid gas and water: it has also been mentioned, that the air we expire contains a considerable quantity of carbonic acid gas.

We have seen in the preceding chapter that the quantity of carbonic acid thrown off from the lungs in twenty-four hours, corresponds to ten ounces carbon: hence, the loss from this source alone (without taking into account the hydrogen, carried off in the same manner) amounts to seventy ounces, or very nearly four and a half pounds per week, or a quantity equal to the weight of all the carbon in the body (fourteen and a half pounds) in about three weeks.

The carbonic acid and water thus eliminated, are to be regarded as the remains of certain constituents of the body, removed from the blood by the agency of air. This process takes place in the lungs.

The lungs consist of a most elaborately-devised structure for affording communication between the blood and the atmosphere. The arrangement of these important organs allows a part of the air to enter the blood, and also of gases in the blood to mingle with the air, without any actual contact taking place between these two very dissimilar bodies.

Without entering upon any detailed account of the structure of the lungs, we may remark that they consist of a multitude of minute cavities or vesicles, through the delicate walls of which air and gases can pass, though liquids cannot. The number of these cavities is prodigious, and their size extremely small; yet each is provided with three sets of vessels; one to bring the blood that needs a new supply of oxygen, and freeing from carbonic acid; another to bring air, which supplies the oxygen thus required, and also affords a vehicle by which the carbonic acid escapes; and a third set of vessels to take away the blood thus rendered fit to begin its rounds again.

The purpose of this incessant transference of materials from the body to the surrounding air is twofold. By means of it the system is freed from a certain class of substances which, having performed their office, have become vitiated, and are dismissed through this channel. The chief object, however, carried out by this arrangement, is to provide a source of heat or warmth. A certain temperature always pervades our bodies; it being one of the conditions necessary for the action of all vital functions. This amount of heat is obtained by slow oxidation, in every part where the blood penetrates, of compounds having an affinity for, or inclination to unite with oxygen. These compounds furnish the products of respiration above alluded to, while the compounds themselves are prepared from that class of food we have described by the term "respiratory." The result of this oxidation is, in all cases, the production of heat or warmth.

It needs but a moment's reflection to show that this internal warmth of the body is altogether independent of the warmth of the air that may surround us. Although an exposure to heat or cold may temporarily reduce the temperature of the extremities, and, perhaps, the surface generally, whereby more or less discomfort and derangement may ensue, yet no general departure from the normal heat of our bodies ever takes place during life.

Our bodies are as warm in winter as in summer : again, the blood of men living even in the arctic regions is no colder than of those living in the tropics. This is because all the functions of the body require to be maintained at a particular temperature, which must be preserved independently of every change of climate we may be exposed to, or serious derangement results.

In cold weather, we part with a great deal of heat or warmth to the surrounding air, and to all cold objects we handle. This loss must obviously be at the expense of the above-mentioned source of vital heat; but as this is capable of increased action, within certain limits, no general reduction in the temperature of the body results under these circumstances.

Healthy persons, at this season simply require an additional quantity of food; especially of that class of materials richest in respiratory compounds; since, when the functions of digestion, &c., are in good order, any sensible loss of heat from external sources is met by an increased consumption of food, which, thus augmenting the supplies of respiratory materials in the blood, affords, by its oxidation, an amount of heat, which being equal to that conducted away, maintains the desired standard, and no inconvenience is felt.

It is for this reason that healthy persons require more food in winter than in summer, and why we may eat in cold weather, even with a relish, an amount of fat which in summer would be distasteful, or even repulsive. We have all heard of the inhabitants of northern latitudes eating candles and train oil. It is only by some such diet that life can be supported, even by healthy men, in regions where every breath of air taken must be paid for by the loss of a great amount of heat; and this leads us to remark that the heat we lose on exposure to cold, even when improperly clothed, is chiefly lost through the lungs in the expired air. The large quantity of cold air received into the lungs, must all be warmed to the temperature of our bodies, at our expense, before it is exhaled. It is for this reason that invalids suffering from any internal derangements which interfere with the preparation of respiratory material in the blood, cannot sufficiently protect themselves from the severity of climate by external coverings of extra clothing.

Thus, the internal warmth of our bodies, indispensable for the continuance of all vital processes, is dependent on the action of the free oxygen of the air upon certain compounds in the blood, prepared from that class of food we have called respiratory: such as sugar, starch, &c.

The production of heat, in this manner, is dependent on the same principles which govern the liberation of heat from the oxidation of fuel in a fire or candle. In either case a definite amount of heat is the result of the conversion of a definite amount of oxidizable elements, either carbon or hydrogen, into their respective oxides (carbonic acid and water): hence, the richer the fuel or the food is in these elements, the greater its effect. We must not forget, however, that, in the case of food, its value in this respect is qualified by its facility of digestion and general wholesomeness. This is the reason why the Esquimaux esteem tallow candles a delicacy,—tallow being, like all other kinds of fat, extremely rich in carbon.

If the supply of respiratory material is greater than is required, the excess, within healthy limits, is stored up in the shape of fat; indeed, the greater part of the fat present in our bodies may be regarded as a reserve of combustible material, to meet any unusual falling off in the regular supply.

LOSS OF SUBSTANCE BY MOTION OR EXERTION.

Another and more important source of loss to our bodies arises from the actual wear and tear of every part of the frame, consequent on its movement or exercise. Our limbs are not altogether exempt from the rule of destruction or consumption by use, which affects more or less all material objects, although we generally remain unconscious of the fact, for reasons that will presently be explained.

Every movement of a limb, for instance, entails a certain loss or removal of substance from the tissues of the muscles which produce the movement; and although the quantity of material removed by a single movement is but small (just as is the loss of material by a single breath expired, as above noticed), yet the loss produced by prolonged exertion amounts to something considerable, and sufficient to necessitate a more elaborate provision for its replacement than in the case of the respiratory function we are already acquainted with.

This loss of structure being, as we might suppose, in direct proportion to the extent of movement or action, is greatest in those parts subject to continued, and often very active, movements; such as the muscles; and especially in those which take part in the voluntary movements, loss in this way is very great.

We need, perhaps, hardly mention that the movements of our limbs, or of our bodies, to any new posture, or even their support in ordinary attitudes, as sitting and standing, depend on the action of those extraordinary structures called muscles, or commonly, flesh, which clothe the skeleton externally, and furnish a necessary source of independent movement and strength, and, at the same time, by their marvellous arrangement, determine the graceful contour of the human form.

A muscle may be familiarly likened to a rope capable of pulling itself; that is to say, one end being fixed, and the other end attached to some movable object, it possesses the power of drawing up the movable object by contraction throughout its length. The origin of power or strength in the muscles is still one of the most obscure problems of physiology. All that is definitely known concerning them is, that for every contraction or exhibition of their peculiar function, a loss of the organized tissue of the muscle is incurred, and that the chief reason why all movements of a muscular origin cannot be continued, indefinitely, is in consequence of the failure of the supply of this tissue.

It is this loss in the substance of the muscles, as well as of the nerves which control their movements, that gives rise to the sensation of fatigue, and determines the necessity for rest and sleep; as it is chiefly during this latter condition that the loss in the muscles, and especially the nerves, is repaired from the source we shall presently point out.

The material concerned in the above-mentioned operation, consists of organized products, whose chemical composition resembles the albumen of the blood, and which is the only source whence they can be replaced.

The purpose of this, at first sight, needless waste, or consumption of organized tissue, is to supply strength, force, or power, which, exhibited in the muscles as tangible strength, manifests itself in the internal organs as functional action, or the power to carry on the peculiar offices allotted to them.

Although the production of these effects from the consumption of organized tissue is by no means so clear as the connection of heat with the consumption of respiratory compounds, it is believed that the consumption of certain parts of the structure of an organ (as a muscle, for instance) is the immediate cause of the power or action it exhibits. At all events, there exists a constant relation between the amount of force or action manifested, and the organized material consumed; but, at the same time, it is highly probable that the easily oxidizable compounds of the blood—the so-called respiratory principles—take some share in the development of strength, and other kinds of functional action.

Recent science has shown that force or power, whether of animal origin or otherwise, can only be developed or liberated from some compounds capable of furnishing it in definite quantity. It is quite as impossible to create force or strength as it is to create material substances. Hence our bodily strength, however elicited, is undoubtedly derived, in the first instance, from the materials we consume.

The foregoing remarks must not, however, be thought to imply that a muscle or other organ, becomes permanently weakened by use. All experience agrees that the contrary is the fact; and this is in no way inconsistent with what has been said; viz., that a loss or consumption of organized tissue accompanies every movement of a muscle, this loss being proportionate to the exertion undergone.

The truth is, that the exhibition of action in a muscle not only involves a loss of its tissue, but at the same time excites and improves the conditions for its restoration; provided, of course, adequate supplies of new material are at hand, and the vital power of renewal is properly active. Thus, although a muscle, or series of muscles, as those of a limb, for instance, lose by increased action, an increased amount of their organized structure, yet, on the cessation of this action, it or they will not only repair the loss sustained, but will have appropriated more material than before, and be better able to bear a repetition of such exertion. This result depends chiefly upon the fact, that the supply of blood (the source of all new substance) to a part, is favoured by its exercise.

The most essential condition for the development of muscular structure is, in fact, a frequent but gentle manifestation of action; or, in other words, of exercise within reasonable limits.

It has been proved beyond a doubt, that, however rich the blood may be in albumen and the mineral salts whence the muscles are built up, or however active the organic power of renewal in these organs may be, the muscular development will not proceed, or, in other words, we cannot get strength without exercise; for the simple reason that exercise or use is the most necessary condition, not only for maintaining the vigour of muscular structure, but for allowing of any augmentation therein which the system may be susceptible of.

The renewal or renovation of muscular tissue, and, consequent storing up of strength, proceeds at all times, but at variable rates of progress. It is most active during sleep, when a regular, though reduced flow of blood through these structures, as well as through every other part of the frame, allows the organic power of appropriation to proceed uninterruptedly. It proceeds, however, at all times in the intervals of active movements, and probably, also, to a small extent, even during moderate exertion, as is shown by our ability to continue a moderate exertion for several hours without any prolonged cessation.

The facility with which new material is appropriated or organized, and consequent ability on our parts to continue exertion, is influenced mainly by the degree of inherent tendency to health (which may be defined as the natural balance of functions), or what is commonly called our "constitution."

It is this which chiefly determines the amount of exertion we may undergo with impunity or with benefit; a power altogether different from strength arising from muscular action.

Not only the muscles, but every other part of the frame, suffers a constant degradation of its substance, corresponding to the amount of activity required of it. Even the bones, which are the most solid, and, perhaps, also the most staple parts of our bodies, are not exempt from this law of wear by use; while the brain and nerves (probably from their exceeding delicacy of structure) are peculiarly susceptible to exhaustion by exercise, as is evidenced by our inability to continue for a length of time, without great effort, any arduous mental labour.

In speaking of the brain, we mean, of course, the material instrument upon which the mind plays. The nerves we may regard as extensions of the brain, for affording communication between it and every part of the system: by means of these, all voluntary action is transmitted by the miraculous power of the will.

By all mental exertion a consumption or degradation of the substance of the brain takes place; and although the effects of the loss are not, amongst persons generally, so soon made evident as that arising from the work of our hands and limbs, yet the exhaustion we suffer from this source is proportionately greater than from the preceding cause; while any over-exertion of the mental faculties is less easily borne by the system than an excess of bodily labour.

MODE OF REPLENISHMENT.

The source whence replenishment proceeds for the loss of either kind above spoken of, is the blood, the one primary reservoir of every kind of material required in every part of the system. The blood travels round to every muscle, every nerve, even into the interior of the bones,—in short, to every part where new material is required; being a common store of nutriment, from which each particular organ can find in it those materials it needs for its own support.

The materials brought by the blood for the renovation of the structures above more particularly referred to, viz. the muscles, or sources of strength, are albumen and certain mineral salts, already mentioned as constituents of this fluid. It will, however, assist our comprehension of the subject in hand, if, for the present, we put aside these mineral salts, and speak only of albumen.

From this extraordinary compound, as it exists in a fluid state in the blood, the greater part of our entire structure is derived. It is directly appropriated and organized in the muscular fibre and other primary structures, which resemble it closely, as regards chemical composition, and differ from it mainly in having been coined, so to speak, in Nature's dies. Albumen is also the indirect source of other, and what we may call secondary structures, which differ in composition more or less from it, but are yet fed from it, when, by a slight transposition, in the way we shall point out, it has become adapted to their wants. The latter sentence will, perhaps, be better understood, if we remark, that the loss or consumption of plastic compounds involved in the above-described departments of our internal economy, does not take place suddenly or directly, but gradually, and step by step, as it were.

Thus the organized products consumed in the exercise of a muscle are probably not rendered entirely useless and fit only to be at once carried away. Although no longer serviceable for this purpose, they probably become available for some other inferior structure, such as a tendon; for instance,—the strings, which apply the power of a muscle to the part it is intended to move; as the "leaders" or tendons (or perhaps these may be the "thews!" known to novelists) of the wrist, which connect the fingers with their muscles in the forearm. These and similar structures are composed of a substance of a secondary character, that is, having a simpler composition than the muscles themselves, or, in other words, are composed of albumen, minus certain of its constituents. Again, having done duty as a tendon or similar structure, the same material probably becomes serviceable for some other structure of still lower grade; and so on, until it reaches the lowest of organizable structures.

Thus the changes proceeding in our bodies are, for the most part, characterized by a resolution, or a breaking up of complex compounds into simpler ones. The highly complex combinations in food undergo, while in our service, a constant degradation until having reached a point at which they are no longer serviceable, are dismissed, and return to the laboratory of nature, there to begin afresh the course they have been appointed to carry out.

We have already stated that the fibrine of meat, the gluten of bread, and caseine of milk and cheese, and other plastic components of food, all help to supply the blood with albumen, the form into which each of them becomes transmuted during the digestive and allied processes.

We now see a connection between the origin of strength and the repair of all parts of our bodies with those peculiar constituents of food we have spoken of by the term "plastic elements;" a term, indeed, suggested by the illustrious Liebig, as expressive of their great importance in this respect.

The above facts will help to explain why we can eat much, and with a good appetite, if we work hard, and why a person accustomed to active exertion cannot sustain his strength upon meagre farinaceous food. Persons so employed must have either beef or mutton in quantity proportionate to the labour undergone. If the quantity of food, or, what in most cases amounts to the same thing, the quantity of animalized nitrogenous principles of food, falls short of this, we soon suffer more or less inconvenience and injury.

The same result will follow from an inability on our part to digest or assimilate these principles of food, either from their being unwholesome, or from our digestive functions being impaired.

Whatever may be the cause of an interrupted supply of new material, the exertion undergone is still at the expense of that already organized; and hence, if such interruption be prolonged, the system gradually loses power and tone; an effect manifested by a want of strength, and particularly of endurance, or, if in greater degree, by palpable feebleness and emaciation. This happens because it is wholly impossible that the place of these compounds can be supplied by the simpler products devoted to respiration, or from any other source: hence it is clear that an inadequate supply of them to the system, from any of the causes above named, cannot but be productive of the most disastrous results. In each case the work performed is at the expense of tissues not intended by nature to be consumed in this way, and whose consumption entails permanent injury in the organs concerned. In fact, it is not too much to say, that all exertion performed in spite of the warnings given by nature in the shape of fatigue and exhaustion, is performed at the expense of our subsequent health and comfort, to say the least, but in greater degree, without doubt, of our lives.

PURPOSES PERFORMED BY THE MINERAL ELEMENTS OF FOOD.

A LOSS or consumption of mineral matter accompanies that of each kind of material referred to in the preceding pages, it being, in fact, a necessary condition in the functions of respiration, production of strength, and, indeed, of renovation generally.

In these and every kind of vital phenomena, a definite amount of the mineral elements composing the various parts of the frame, are consumed, and rendered unfit for further use in the same way, as we have seen is the fate of the more abundant organic principles of food.

What we have here called the mineral or inorganic portion of food, is most intimately associated in the functions alluded to in the foregoing pages; but the share this class of materials takes therein is not so well understood as in the case of the more abundant compounds referred to.

In order that the importance of the mineral elements of food may be duly appreciated, we may call to memory what was formerly stated; viz., that the separation of the constituents of food into organic and inorganic groups, merely because one class is convertible into volatile products (the organic), and the other is not (the so-called mineral), is altogether an arbitrary proceeding. The separation of the mineral salts from the respiratory principles of food found associated with them in the mixtures we call food, or the still more important salts associated with the plastic principles in the same mixtures, is not unlikely to lead us to wrong impressions concerning the arrangements of nature in this respect, unless especial care be taken to explain that such a classification is almost necessary to make this subject intelligible to persons not supposed to have acquired any previous knowledge of chemistry.

The classification of the elements of food, and, indeed, of our bodily structure, now under consideration, into organic and inorganic or mineral elements, has been adopted, in the present instance, only from the conviction that a more natural arrangement would be much less comprehensible to the class of persons for whom this work is intended, and, therefore, less likely to be read with any interest, and to be productive of any good.

We may now, however, briefly relate that the essential parts of food are, no doubt, definite, very complicated, and but little understood, combinations of the mineral elements, such as phosphoric acid—the salts of this acid, &c., with the more abundant compounds we have become acquainted with by the names of respiratory and plastic compounds. These latter are but the constituents of food as revealed to us by the comparatively violent separation to which we expose the various articles of food in our researches into its composition; but there is no probability that these are the compounds accepted by Nature for the sustenance of our bodies. Her arrangements are far more elaborate than we are always ready to believe; so much so, indeed, that the highest authorities in these matters admit that all the labours of chemists and physiologists, in the subjects of animal nutrition and the relations of the constituents of food therewith, have but revealed the index, so to speak, of an inaccessible volume.

Yet the comparatively little that is known of these subjects forms, at present, an extensive branch of human knowledge, of which the preceding and present pages are but a small portion; it also affords a clue, to those pursuing these investigations, towards the extensive regions of what is at present beyond our reach. Notwithstanding what has been said above, this clue is sufficiently tangible and promising to those initiated, to encourage them to devote the best of their efforts to the unravelling of matters connected with these subjects, which to others may seem useless and hopeless.

But to return. It has been shown, by conclusive experiments, that the albuminous or the respiratory principles, either separately, or when mixed in any proportion, are unfit for service in the body, unless accompanied by the mineral salts always found associated with them in wholesome food. Yet these mineral salts, again, when separate, though even mixed in the proportions found in food, are wholly unfit for supporting life; indeed, they produce effects altogether different from those of food. But, further, any artificial mixture of the organic principles with the mineral salts, as in imitation of those occurring in food, wholly fails in its intended effects.

Thus we are justified in assuming the existence in food of intricate combinations, in which many, perhaps all, the materials present take part, and which, arranged *only* in this manner, constitute wholesome nutriment.

If we may venture to speak of the comparative value of the three classes of food-constituents brought under notice, we should say the mineral elements are the most valuable, inasmuch as they seem to be more connected with the machinery of the various organs, if the expression may be used, rather than with the products they manufacture, which, by their consumption, give rise to the characteristic functions of the organ. Thus no kind of food is so effective in restoring tone and vigour, after exhaustion by illness, as the essence of meat described in an ensuing chapter. This product acts in this respect chiefly in virtue of the large proportion of mineral salts, already partially arranged for animal requirements, which it contains.

Again, the superior nutritive value of potatoes in comparison with rice, both being usually classed as of the same description of food, is no doubt attributable to the larger quantity of useful mineral matter present in potatoes.

The mineral elements of food being thus so important in the various purposes it is intended to fulfil, we can readily imagine that any circumstance which causes their removal from the natural mixtures in which they occur, must create more or less disturbance when these mixtures are received into the system as food. For instance, if much of the meat we eat has been boiled, and that in an injudicious manner, we are likely to suffer in health from the want of those salts extracted from meat by this mode of cooking, the supply of which, in an *animalized* form, being without doubt the principal circumstance upon which the value of this kind of diet depends. Again, the instances before mentioned in connection with salted provisions also tend to show the superior value of the mineral salts occurring in food.

CONNECTION OF THE PRECEDING SUBJECTS WITH THE SELECTION OF FOOD.

The foregoing remarks will perhaps lead us to perceive that in our choice of food some regard should be had to its quality as regards ability to furnish a proper quantity of each kind of material required for the maintenance of our frames. Although it is, of course, not to be expected that we should choose the components of our meals according to precise rules, yet some modification of diet, to meet the requirements of age, sex, mode and condition of life, &c., are certainly worthy of attention, as the increase of comfort and happiness capable of being thus obtained, especially in the case of persons not altogether robust, amply repays the little trouble and self-denial incurred in their observance.

To some extent we are instinctively guided to the kind of food best adapted to afford us sustenance; but as we too often eat merely for the pleasure of eating, wholly regardless of the purposes food is intended to perform, we certainly make great blunders in this matter, and thereby often incur the chastisement of Dame Nature.

At the same time, no one can with sincerity ignore the pleasure of eating, nor should it be lost sight of in the choice and preparation of food. Every kind of aliment should be as palatable as possible: all ill-flavours and non-flavours are failings to be overcome by those to whom the procuring and preparation of food is intrusted.

It is true that, under favourable conditions, great liberties may be taken with the digestive functions almost with impunity, and an occasional excess of food is no doubt harmless in most instances. Notwithstanding this, however, a knowledge of the theory of food as regards its quality and right proportions of its several constituents, &c., is likely to afford much aid to common sense in the preservation of health, especially in regard to that of children, who are, for obvious reasons, more susceptible to injury from this source than adults: they have, moreover, a moral claim to all reasonable protection in this way from parents or others on whom they are necessarily dependent.

It is true, most of the mistakes made in the way of eating are voluntarily indulged in by men who partake too freely of the good things of the table; but an ignorance of the nature of food, too often leads us to make more serious blunders in the opposite direction. Grievous injury is sometimes unconsciously inflicted on children and young persons by withholding from them necessaries which are believed to be luxuries. For instance, the system, formerly very common and still necessarily pursued at unreasonably cheap boarding-schools, of feeding children, to a great extent, upon pudding and rice, with but little meat, is a serious mistake of this kind. Such a system is scarcely compatible with health under the most favourable circumstances; but when, at the same time, the mental faculties are actively exercised, and often overtasked, it is wholly impossible that such treatment can be endured for any length of time without permanent injury to the constitutions of the children exposed to it.

We may now proceed to speak of the relative value of different sorts of provisions, also the quantity and composition of food best suited for sustaining health. An idea of the comparative value of food may, perhaps, be formed from the following remarks.

A quarter of a pound of good beef, as cut off the best part of a cooked joint and consisting of fat and lean, in the proportion commonly eaten, contains—

Nitrogenous or strength-giving materials.	Respiratory, or warmth-giving materials.
421 grains	595 grains
(Equal to about one ounce.)	(Equal to about 1½ ounce.)

We have taken this quantity of beef as a standard for comparing the relative nutritive value of some of the more common articles of food. In the following table is shown the quantity of provisions which respectively contain as much nitrogenous matter as a quarter of a pound of cooked beef. We also give, in a second column, the quantities of respiratory material furnished by these quantities of provisions :—

Quantities containing 421 grains (or about one ounce) of plastic material.			Quantities of respiratory material also present.
lbs.	oz.		oz.
0	6	Beef, in raw state	1¼
0	10¾	Bread	6
0	4	Cheese (Double Glo'ster)	1½
1	6	Milk	1¾
2	10	Potatoes	7¾
4	4½	Boiled rice	14
0	4½	Dry peas (split peas)	2
0	4	Dry beans (haricots)	2
1	8	Green peas (cooked)	1¾
1	9	French beans (do.)	1¾
0	8¼	Flour (in natural state)	6
0	6¼	Oatmeal	4¼
0	8¾	Barley-meal	6¾
3	12	Cabbage	2½
9	1¾	Carrots	11½
6	0¾	Turnips	5¼

The above table is intended to serve as some guide to the admixture of food, especially in the preparation of soup, and other articles of the kind more particularly dealt with by economical cookery.

All suggestions for the admixture of these substances must be left to the taste and judgment of those who are interested in the result. Again, we think it desirable to omit all mention of the comparative money value of the above-named provisions, for the obvious reason, that any prices we might assume to be an average would necessarily become incorrect, from the constant fluctuations in the market value of these commodities. Moreover, the extraordinary differences in the value of such articles in different districts, render any calculations of this kind at least useless. An instance of this is furnished by milk, which can be got in many country districts for a halfpenny per quart, and although called skim-milk, is yet far better than the milk usually supplied in towns by the name of new milk, and for which *4d.* per quart is usually charged.

As regards the quantity of food required to support the human frame, no precise information can be given, for the obvious reason that the quantity of food required will also vary with the mode of life, &c. It is found, however, that a healthy man requires about 1¼ lb. to 1½ lb. of dry food, and about 5 lbs. of water (about five pints).*

The annexed diagram may, perhaps, at least be interesting. It is intended to give an idea of the quantity (second and third columns) and general composition (fourth, fifth, and sixth columns) of the food consumed per day by an ordinary person. The quantities of food mentioned, are the round numbers obtained by weighing the portions usually taken at meal-times; in some cases, as of bread and meat, they are the average of several portions, taken by different persons. The composition of the various articles of food mentioned, has been calculated from the tables given in the preceding pages.

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* This quantity includes the water in solid food, as well as that in beverages.

APPROXIMATE QUANTITIES AND COMPOSITION OF THE FOOD TAKEN DAILY BY AN ORDINARY MAN.

	Water.	Total dry substances.	Nitrogenous, or strength-giving mater'l	Respiratory, or warmth-giving mater'l	Mineral Substances
At Breakfast:—					
Six ounces of bread	845	1777	234	1435	27
A slice of ham (weighing one and a half ounce)	183	472	62	412	6½
An egg (weighing two ounces)	647	227	112	87	12
Butter, three quarters of an ounce	23	305	17	288	
Two cups of coffee, with sugar and cream	8255	485	55	402	25
	9953	3266	480	2624	70½ gr
In lbs. and ounces,* these quantities correspond very nearly to	1lb. 6¾oz.	7½ oz.	1 oz.	6 oz.	⅛ oz.
At Dinner:†—					
Six ounces of meat (beef)	1062	1560	629	904½	27 ‡
Four potatoes (two ounces each)	2710	786	84	666	21½
Four ounces bread	564	1185	156	957	18
Cheese (three quarters of an ounce)	116	·211	71	125	14½
Pudding, made of sago, with sugar, &c., in ordinary manner, weighing three ounces	578	722	29½	650	13½
Beer, one pint	7780	434	60½	347 (exclusive of alcohol)	27½
	12810	4898	1030	3649½	122 gr.
These quantities expressed in ounces, correspond to—	1lb. 13oz.	11 oz.	2¼ oz.	8¼ oz.	¼ oz.

At Tea:—					
Three ounces of bread	422	888	117	717	13½
Half an ounce of butter	15	202	105	192	2
Two cups of tea (with sugar and cream)	5803	315	26	276	12
	6240	1405	148	1185	27½ gr
These quantities expressed in ounces, correspond to—	14 oz.	3¼ oz.	¼ oz.	2¾ oz.	—
At Supper:—					
Three ounces of bread	422	888	117	717	13½
One ounce of cheese	155	282	95	166	19½
Beer as at dinner	7780	434	60½	347 (Exclusive of alcohol)	27½
	8357	1604	272	1230	60·5
Expressed in ounces—	1lb. 3oz.	3¾ oz.	½ oz.	2¾ oz.	—

SUMMARY OF ABOVE TABLE.

	lbs. oz.	lb. oz.	oz.	lb. oz.	oz.
At breakfast	1 6¾	0 7½	1	0 6	⅛
At dinner	1 13	0 11	2¼	0 8½	¼
At tea	0 14	0 3¼	¼	0 2¾	¼
At supper	1 3	0 3¾	½	0 3	
	5 4¾	1 9½	4	1 4¼	⅝

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* Ounces being but a rough expression of weight, and drachms, or other divisions of the ounce, not being generally understood, we have thought it best to express our detailed quantities in grains (437½ grains = 1 oz. avoirdupois), and afterwards, our totals in ounces.

† In order to avoid unmanageable complications, plain fare only has been chosen for our example, and this is supposed to be taken in the vulgar manner of four meals a day.

‡ These quantities are exclusive of salt taken at meals. A ladleful of salt weighs about 35 grains.

The proportions of plastic and respiratory materials best suited for constituting human food, seem to be one part of the former to four or five of the latter; but these proportions should be varied to suit our mode of life, state of health, &c. As a rule, the more active exertion we take, the more nitrogenous or plastic matter we require; while persons who lead a sedentary, or in-door life, require but a small proportion of these constituents.

It should here, perhaps, be mentioned that the value of different articles of food cannot be estimated entirely (as lately supposed) by the proportion of nitrogen or nitrogenous (albuminous) compounds it contains. It depends rather upon the relative proportions of the foregoing substances, with the carbonaceous compounds, and probably, also, in some cases, upon small quantities of essential principles we have not yet identified.

CHEMISTRY OF DIGESTION.

We ought here, perhaps, to say a few words about the process of digestion, as it is only through the agency of this important function, or, rather, series of functions, that the food we consume becomes available for the purposes spoken of in the preceding pages. We need, perhaps, hardly add, that the benefit derived from food depends almost solely upon the quantity of it digested, and not upon the quantity eaten.

The process of digestion is, in many respects, a chemical one, since in it the various constituents of food are essentially altered in properties by means of certain agents, whereby they are rendered fit to be assimilated.

The process of digestion, in its early stages at least, may be regarded as one of solution; that is to say, the components of food which are insoluble, or do not admit of intimate admixture with water, or juices whose basis is water, are rendered soluble, and, we may say, are converted into a fluid state: for instance, a piece of cheese, or the white of egg, might be left a-soak in water for a long time before any change approaching solution would take place. Again, meat, or even bread, might be treated in the same manner; and it would be found that, although a portion dissolved, the greater part of either of these solids remains insoluble in this fluid, even after standing some time.

Now, it is essential that all components of food of this character (and the greater part of food is of this nature) be rendered soluble in water, or in fluids whose basis consists of this liquid, in order, first, that the requisite separation and rearrangement of their constituents according to the requirements of the system, may take place; and, secondly, to allow of their passage through the minute absorbent vessels, and others equally minute, where the subsequent process of nutrition proceeds, and where fluids only can penetrate.

It has been found that if solid animal food of the kind above mentioned be placed in water to which a few drops of hydrochloric acid have been added, and the whole kept at a temperature of about 100° Fah., solution slowly proceeds; further, if to this mixture a small piece of rennet (the prepared stomach of a calf, used in making cheese) be added, the solution of the insoluble matter is greatly facilitated.

Again, the insoluble vegetable matter—starch, which, as we have seen, occurs abundantly in food, may quickly be rendered soluble if placed in an infusion of malt (the water in which malt has been soaked). In this, and the preceding instance of solution by means of rennet, the solid matter has been rendered soluble by a species of fermentation: a chemical change, slight, but essential, has been effected in the particles of insoluble matter, whereby they have become soluble.

Although we are apt to limit the term fermentation to the change which results in the formation of alcohol from a solution of sugar by the agency of yeast, the term must be used in other cases (since there is no other) where a partial separation and readjustment of the particles of a compound is effected by the agency of another body, which itself undergoes little change. Such bodies are called ferments, and owe their power, in this respect, to their peculiar condition, which is one of incipient change. In the former instance, the ferment is the piece of animal membrane, which, being in a state of incipient solution, communicates this condition to the animal matter adjacent to it, in a manner not very well understood. In the latter case, the starch is rendered soluble by a ferment formerly called diastase, but may be regarded simply as gluten in the condition it acquires by the germination of the grain in which it occurs. It possesses the power of rapidly changing starch into sugar, and consequently of making it soluble in water.

The above-described instances of the solution of food are, in fact, artificial imitations of the process of digestion; at least we may say, that in this vital process, chemical changes closely allied to the above are included. The saliva contains a fermentative principle capable of converting starch into sugar, even out of the body, in the same manner as the diastase above mentioned; while a ferment far more active than the rennet, is afforded by the mucous coat of the stomach itself, which is known to produce a ferment of this character. The acid liquid in the above experiments corresponds to the gastric juice of the stomach, which it closely resembles, even to the extent it has been generally believed, of owing its acidity to the same acid, viz., hydrochloric; but this is, at least, doubtful.

The chief chemical agents in the digestive process are the saliva, the gastric juice, and the bile. Apart from the office of saliva in the manner above hinted, its chief use seems to be to moisten the food uniformly during mastication, and to mix with it *air*, the presence of which in the stomach, in intimate mixture with the food, is undoubtedly one of the essential conditions of a healthy digestion. The admixture of air with the food is admirably provided for by the peculiarly viscous, frothy character of this secretion.

After preparation in the mouth, the food is next conveyed to the stomach, there to be brought under the influence of the gastric juice. The nature of this fluid has long been a difficult problem to physiologists and chemists, and is not yet satisfactorily determined. Its most essential components are, however, a free acid, the organic ferment above mentioned, sometimes called pepsin, chloride of sodium, or common salt, and a few other salts. The solvent action of this curious fluid is found to belong to it even when brought in contact with food out of the stomach; in the living body, however, its action is greatly assisted by the peculiar mechanical movements of the stomach, and by a definite temperature (about 100° Fah.), as well as by several minor secretions. The lining membrane of the stomach, the epithelium as it is termed, is believed to furnish the organic ferments upon which the solution of food mainly depends; but the action of this body probably requires for its development the air, or rather the oxygen, brought by the saliva. The derangement existing in cases of dyspepsia, or indigestion, generally consists in a deficient development of this fermentative principle upon which the proper digestion of food probably mainly depends.

The effect of the gastric juice on the food, aided in the way above mentioned, is to reduce it to a uniform semifluid, of cream-like character, called the chyme. This is now passed out of the stomach into the upper part of the intestines, and there brought under the influence of the bile.

The bile is probably the most important agent in the digestive process, or rather, in the conversion of food into products acceptable to the system as sources of nutriment; it serves to determine the arrangement of the food-constituents into the forms they must assume before they can be assimilated. We may infer this from the fact of the system exhibiting symptoms of deficient nourishment whenever the liver, which, we need hardly say, is the organ whose office it is to secrete bile, fails to act properly, and of emaciation when it ceases altogether. It seems especially connected with the development of available respiratory material from the starch, sugar, and other non-nitrogenous compounds of food; that is to say, with the conversion of these compounds into the forms in which they exist in the blood, and in which they are susceptible to oxidation and consequent liberation of heat, as shown by the extreme susceptibility to cold experienced by persons in whom the supply of healthy bile is deficient.

One of the most important constituents of bile is an alkaline body of the character of soap, and is believed to be the chemical agent in rendering soluble the fatty materials of food.

Having been properly disposed of by the bile, the food is next passed into the small intestines, from which its essential portions, if properly prepared by the above-described agents, are absorbed and conveyed into the blood, there to furnish new material for the renewal of every part of the frame.

The process of digestion, as above briefly sketched, proceeds only when all the conditions laid down by nature are complied with. It is, of course, liable to be interrupted, and its results to vary in quality as sources of nourishment, by the quality and quantity of the food we take, and especially by our manner of taking it. It is especially likely to be interfered with by too much food, since Nature makes preparations only for the amount of food she requires, and all above this quantity only impedes the proper digestive process. The gastric juice secreted by the stomach, and varying in amount chiefly with the requirements of the body, can only dissolve a definite amount of food; and if more be taken, it must either remain undissolved till more gastric juice be secreted, or, what is more common, be expelled from the stomach in a partially dissolved state, and in its passage through the bowels in this condition, irritates them, and gives rise to more or less derangement. Moreover, if more food is taken then can be dealt with by the agents above spoken of, especially if it be of a heterogeneous kind, as is commonly the case, all kinds of abnormal fermentations are set up, which, besides creating the disagreeable sensations which Nature inflicts as a punishment for indulgences of this kind, of course impede the elaboration of healthy nourishment, and, if habitually repeated, are likely to injure the digestive functions.

Again, the manner of eating influences, to no small extent, the effect of food on the system. If swallowed while in an imperfectly masticated state, the stomach is not only exposed to extra mechanical work, but is deprived of the chemical action of the saliva, as above spoken of.

Lastly, as a comparatively elevated temperature in the stomach is an essential condition for a wholesome digestion, anything which tends to reduce this unnaturally, interrupts the process: hence the taking of large quantities of cold liquids while eating, especially at dinner, should be avoided.

Since it is only that portion of food which becomes fully elaborated by the process of digestion, &c., that can enter the blood, and become available as actual nourishment, it is clear that the consumption of indigestible or otherwise unwholesome food, or the possession of an impaired digestion, will be tantamount to an insufficient supply of food. In preparing mixtures of food, we must, therefore, of course, regard not only their composition, but also their digestibility and general fitness for food. As these qualities are to a great extent dependent on the care and skill bestowed on the cooking and preparatory processes, we may again point out the importance of this branch of domestic economy.

A few remarks upon certain general derangements arising from the disturbance of Nature's arrangements, in respect to our sustenance, may not, perhaps, be out of place.

Although we may live, and even work, for a considerable time without adequate food, we cannot long do this without detriment to health, or, if prolonged, without endangering our lives; because, under these circumstances, we derive our strength at the expense of our own constitutions, as explained at a preceding page; in other words, we consume our capital instead of the interest thereof. A very similar result follows upon prolonged exertion, either physical or mental, to an unreasonable extent; because our systems can bear with impunity only a definite amount of exercise, and if this amount is repeatedly exceeded, permanent injury must result.

The consequences of deficient food, as well as excessive bodily exertion, are still more severe upon children and young persons who have not reached maturity; for the obvious reason, that at this period of life a considerable amount of the vital energy is disposed of in the enlargement and development of every part of the frame. If this natural arrangement be interrupted by a too close application to work, the bodily powers either entirely succumb in early death, or, what is more common, Nature agrees to a sort of compromise; and the result is, that instead of the bodily development being carried out, to the proportion belonging to the human frame, it becomes more or less stunted or deformed : hence, we can account for the ill-made forms so common amongst the worst off labouring classes.

A disordered state of body, of a character somewhat similar to the above can, however, arise with a proper supply of food, from our not complying with the conditions established by Nature for its being properly disposed of. Such derangement may arise from our neglecting to take proper exercise, or from a deficient supply of air, and especially from a disproportionate exertion of the various departments of the body. A common cause of such affections is an undue exercise of the mental faculties.

It is for this reason that persons who, from the peculiar circumstances in which they are placed, or from peculiar tastes, exercise the mental faculties disproportionately, become delicate of body, and unable to endure any prolonged exertion, or to encounter with impunity any occasional hardship they may be exposed to. At the present time, when a large proportion of men, especially of the inhabitants of large cities, have to work very hard with their brains for a subsistence, and thus exercise the mental powers more than Nature has provided against, more or less derangement of this kind is very common, especially in cases where no care is taken to counteract this result or to avoid its aggravation.

This kind of derangement may in part be thus explained. A disproportionate exercise of the mental faculties robs the other members of the body of their due share of blood, and also of the stimulus of exercise, and consequent nourishment.

The digestive organs especially suffer in this state of things; since it is known that a close sympathy, of an inverse character, subsists between the digestive functions, especially the liver, and the brain.

The materials consumed in the exercise of the brain are of the same nature, but more intricate, *i.e.* more organized, as those we have spoken of as required for the renovation of every part of the body, and, like them, can only be prepared from the food through the agency of the digestive functions. Now, if these functions, from the causes above mentioned, receive less than their share of attention, they fail to prepare enough new material to satisfy all demands, and a general reduction of health takes place. Moreover, as, in this state of things, the brain is the more vigorous organ, it gets the best share of this diminished supply of nutriment, and hence tends to increased derangement.

Most cultivated persons of the present day admit that a vigorous and wholesome intellect is best sustained with a thoroughly healthy body; it is, therefore, to our interest to cultivate, with at least equal solicitude, the best means of developing the one as the other. To this end we should encourage, in young persons especially, but in all of suitable ages, the love of athletic and outdoor amusements of an innocent and wholesome character. This principle has long been recognized by the better classes of society in the education of their children; and although parents of this class may sometimes make an error in allowing their children a too great immunity from the restraint the majority of persons experience in acquiring intellectual culture, yet this error is but a slight one in comparison to that in the opposite direction, more frequently made by certain classes of persons. The error we allude to, consists of a mistaken anxiety on the part of parents, that their children shall lose no chance of worldly advancement from the neglect of the cultivation of their "talents;" and hence make the cruel blunder of taxing the poor brains of their children from an early age, in the acquirement of every sort of superfluous knowledge, often with entire disregard to all natural bodily requirements.

On the other hand, we often meet with individuals enjoying the most robust health, whose mental powers are of the feeblest character. Persons of this type are commonest amongst the more wholesomely occupied labouring men, who, from early youth, have seen little but work of a laborious, though mechanical description. In cases of this sort, it not unfrequently happens that the force and energy derived from the often meagre diet at command, is so wholly consumed, and sometimes overdrawn, by the day's labour, that any further exertion beyond this through the mental faculties, as would be necessary for anything approaching an intellectual pursuit, is next to impossible. We must not, therefore, be too hard upon men so situated, if their scanty leisure is spent in sensuous enjoyments.

On the other hand, persons who are unaccustomed to active exertion, and lead an indolent, and especially an in-door life, can live very well upon a simple farinaceous diet, that would starve any one otherwise situated.

We are perfectly well aware, however, that such a diet is seldom liked by persons so situated, who generally prefer a richer fare. We should not, however, forget that any habitual indulgence in rich food, greatly in excess of what is required for the support of the body, is extremely likely to produce disease.

It is, no doubt, true, that most of us take more food than we require; and although Nature will bear much neglect in this respect, and has even adapted the human system to accommodate itself, in a measure, to this kind of ill-usage, we must not forget that it is by taxing our bodies in this way that we incur a large proportion of the ailments of life.

PURPOSES SERVED BY LIQUID FOOD.

It must be understood that the solids occurring in, and forming part of, the various fluid commodities described in a former chapter devoted to this subject, pursue, when taken into the system, a course but slightly different to that above spoken of as followed by solid food; except that, as the solids occurring in beverages are, for the most part, already in solution, the process of the conversion into available nutriment will necessarily be simpler. The actual liquid basis of these mixtures, viz. water (with, perhaps, also alcohol), only follows a separate course, and performs a separate purpose in the system, which we have now to consider.

Although the division of the commodities in general use for eating and drinking, into solids and liquids, offers many points of convenience in describing them, there are few real grounds for such a division; since there is much less difference between liquids, *i.e.* beverages, and what we commonly regard as solid food, than we should at first imagine. For instance, green vegetables, fruit, and even meat, contain, as already shown, a large proportion of water, not much smaller, indeed, than in many liquids, as soup or milk. Soup of good quality sometimes contains 20 or more per cent. of solid matter; while milk contains 12½, and sometimes 14, per cent. of dry substance. Thus the difference between solid and liquid food depends more upon the presence of certain solids, or liquids, peculiar to each class of substances, rather than upon the amount of water.

Probably the most important material furnished by all kinds of liquid food, or beverages, under ordinary circumstances, is water; inasmuch as this fluid forms, as we have seen, a very abundant and essential constituent of our bodies, and is, therefore, intrinsically, as important in this respect, as either class of nutritious solids treated of in the preceding pages. Further, as in the case of the solid principles of food, whose offices in regard to us we are already acquainted with, a continual loss, or consumption, of water takes place in our system, in far greater quantity than in the case of the solids referred to, although this loss takes place in a simpler manner, as we shall presently explain: hence the supply of this fluid to the system is, if possible, more urgent.

If we overlook for a moment the exceeding abundance of water, and compare it with other constituents of food, apart from all economical considerations, we perceive that it possesses a higher value than we usually attach to it. In the extent of its connection with all vital processes, water far surpasses all other constituents of food; it is, in short, the one great medium, or vehicle, for allowing all the materials composing our bodies to display their particular offices one towards another, so that, together, they may fulfil the task allotted to them of providing a temporary habitation for our immortal souls.

The manifold services performed by water, as a constituent of our bodies, are all dependent on certain mechanical, or rather physical, properties belonging to it, altogether distinct from its chemical characters. The chief of these properties is its power as a solvent, or its power of taking up solids in a chemically divided state, and carrying them to the remoter parts of the system, as already noticed in speaking of digestion.

The mode of supply, and the nature of the loss of water to and from our systems, is of a much simpler character than that affecting the solid principles of food. This is because the water imbibed in the beverages we take, at no period of its course through our system undergoes any chemical change; that is to say, it never becomes changed into anything else, as other materials do, but performs all its offices in the blood, as well as in every other secretion, &c., as *water*. Water in definite quantity forms, as we have already mentioned, an essential part of nearly every organized structure, and is brought in contact with every material that takes part in our structure; yet the varied phases it assumes in these cases, are imparted chiefly by the organized solids it holds in solution, or that are otherwise associated with it.

Apart from the primary office of water as the fluid basis of the blood, and all other fluids of the body, it fulfils other subordinate, but no less indispensable purposes as a component of our system, which may now be enumerated.

A constant loss of water proceeds from the lungs in the process of respiration; although a part of this water has probably been formed in the blood from the oxidation of the hydrogen contained in the respiratory principles of solid food, the greater part of it, however, consists of water evaporated from the moist surface of the lungs; a result consequent on the increased temperature acquired by the air when in contact with these organs. The water passing off by this channel, departs in the shape of steam, which generally remains invisible in summer time, and while we are in-doors, but becomes visible when the air surrounding us is at all cold,—that is, cold enough to condense this steam into water, which now shows itself as the wreath of white vapour arising from the breath in cold weather.

Another, and perhaps more extensive evaporation of water, proceeds from the skin. This elimination of water (also in the shape of invisible steam) proceeds at all times and seasons, but, as we might suppose, with very different degrees of rapidity. It is most extensive during warm weather, and is much accelerated at all times by exertion or exercise.

What we usually call perspiration, is merely an accumulation of this insensible perspiration on the surface of the skin, arising from its being produced faster than it can be taken up by the air; but that it proceeds, more or less, at all times, we may satisfy ourselves by noticing the deposit of fine particles of water or dew, upon any cold surface, such as a polished knife-blade, or a bright spoon, &c., which may happen to be brought nearly in contact with the skin.

It is by this means, especially during summer time, that the greater part of the water we take, either separately or in other beverages, is disposed of. One of the advantages secured by this evaporation of water from the skin, is to afford a ready means for the removal of any superfluous heat, which, from continued exertion, would otherwise soon accumulate to an insupportable extent.

As by the evaporation of water a definite amount of heat is taken up, and withdrawn according to a beautiful law that we need not here explain, it follows that the larger the quantity of water disposed of in this way, the cooler we shall become. In hot weather, this provision becomes of the utmost importance, in enabling us to sustain an amount of exertion without inconvenience, that would, but for this, be wholly impossible.

Another and even more important purpose fulfilled by this evaporation of water from the surface of our bodies, depends on the fact that the water, in its passage through the skin, carries with it, in solution, a particular class of impurities, or consumed materials, which Nature has intended to be removed from the system in this mode. If this arrangement be not complied with, the removal of these matters in other ways overtaxes other excretionary organs,—a consequence which always produces more or less derangement.

In order that this important process may be efficiently carried out, and also the one above referred to, it is indispensable that the skin be in a healthy and wholesome condition; a condition, we need hardly say, that can scarcely be attained without the daily application of water to the body generally.

It is not too much to say, that the blooming health so commonly seen amongst the present generation of cultivated persons, is, in a great measure, due to a daily increasing appreciation of the virtues of cold water and hard towels.

A further, and, perhaps, still more important office performed by water, consists in carrying away in solution the chief part of the worn-out materials of the muscles, tissues, &c.; in other words, the *débris* of the plastic principles of food, through the kidneys.

The only other fluid of any consequence occurring in liquid food, is alcohol, commonly called spirits of wine, the effects of which, in relation to ourselves, may now be briefly related. Although alcohol, in a separate state, is a highly injurious substance, if taken internally, and may, therefore, with propriety, be classed amongst poisons, its effects in a diluted state, *i.e.* mixed with much water, as found in the majority of fermented drinks, are not the same even in degree; being harmless, if not beneficial. Substances of this character, which possess totally different properties when concentrated and when dilute, are by no means rare. To mention an instance:—Sulphuric acid, which every one knows by the name of vitriol, which is also equally well known to be one of the most corrosive poisons, becomes, when considerably diluted, perfectly harmless, and has been habitually used, by those employed in lead factories, as an efficient antidote to the injurious effects which, otherwise, are always more or less exhibited in persons whose occupation brings them much in contact with this poisonous metal. Moreover, in common vinegar we often partake of no inconsiderable quantities of this acid, which, though not, of course, to be recommended as a desirable adjunct to food, nevertheless constitutes one of the least harmless adulterations.

The question, however, whether alcohol, in the form commonly taken, is serviceable or not in the human system, is a matter that has been much discussed, even by physiologists, but is still undecided.

For the present, however, alcohol, as a constituent of wine and beer, &c., may be classed with the respiratory principles; and what has been already said of these compounds, applies, in a measure, to the liquid now in question. Since alcohol, from its physical character, admits of an immediate absorption by the blood, and, therefore, of becoming available as a source of respiratory material as soon as administered, it possesses peculiar advantages in certain cases where a speedy restoration of internal warmth is imperative. When taken at meal-times with solid food, or otherwise, it probably acts in a somewhat similar manner; its unquestionable value, in many cases, depending on its ability to at once supply the blood with oxidizable material.

As is well known, alcohol also acts as a stimulant; but its effects in this direction, when taken in any reasonable quantity, are, probably, of a harmless character, or, at most, not more to be complained of than the artificial irritation of the stomach induced by condiments or by hot liquids.

Larger quantities of alcohol taken into the system produce the extraordinary derangement known as intoxication. It is this property of alcohol which renders fermented beverages so dangerous in the hands of thoughtless or of reckless persons.

The vast amount of moral and physical evil which we all know to arise from this misapplication of the various beverages containing alcohol, can only be deplored as a terrible proof of the debasement mankind are capable of, or as a lamentable waste of Nature's gifts, but cannot easily be accepted as an argument against their legitimate use. These liquids, partaken of as domestic commodities (the only character in which we have to recognize them), constitute, as is well known, articles of no inconsiderable value, while, in particular cases of impaired health, they are highly beneficial. At the same time, it is but fair to add, that chemical evidence corroborates the doctrine that healthy persons can do perfectly well without any beverages of this description. Chemical evidence, moreover, goes far to prove that the purchase of beer, &c., by labouring men, as a source of nourishment and strength, is the least economical mode of obtaining it.

PURPOSES SERVED BY AËRIAL FOOD.

LITTLE remains to be said in this place of the purposes performed by aërial food, since, in speaking of ventilation, and in explaining the process of respiration, we necessarily also pointed out the chief uses of air. A few other remarks, however, in connection with the subjects of the present chapter, must now be added.

The oxygen of air as a constituent of blood is also connected, though in a less easily explained manner, with the plastic, or strengthening principles of food, and, through them, more or less with every vital process.

Again, we have seen that the air is an important agent in digestion. The effects of fresh air in imparting an appetite are, no doubt, owing to a similar action, apart from its general invigorating effect. The air mechanically carried into the stomach with the saliva, probably acts as a natural stimulant, by exciting its coats to a healthy action.

A very interesting modification of oxygen occurs in the atmosphere in minute and varying quantities, which is believed to exercise a no insignificant influence on our health and spirits. This substance is called ozone. It is found most abundantly in the freshest and purest air, particularly that over the sea. The admirable effect of fresh air in bleaching, purifying, and sweetening everything exposed to it, is, no doubt, chiefly owing to this curious agent.

The influence of fresh air in mitigating the effects of undue indulgence in eating and drinking, is well known; especially if obtained in conjunction with active exercise. This must needs be the case; because it is chiefly upon the assistance afforded by air, or rather oxygen, that Nature depends for freeing herself from the effects of any ill-treatment in this direction, while, as already stated, one of the chief benefits derived from exercise consist in its augmenting the supply of oxygen to the blood, and thus favouring the action of oxygen in this way.

On the other hand, hard work, with insufficient food, is, of course, most severe upon those whose lives are spent in an unwholesome atmosphere; since the injury done by the former evils, instead of being mitigated by the air breathed, as is the case in many kinds of ill-paid but open-air labour (agricultural labour, for instance), is but augmented; because a further effort is entailed upon Nature to hold her own, or, in other words, to resist aggression from an additional enemy.

Having in a previous chapter described the more objectionable of the foreign substances commonly found deteriorating the air we breathe, it is proper now to call attention to the fact that the presence of these impurities (all of which are, more or less, prolific in the atmosphere of large towns), even in small quantity, is by no means harmless: nor, when in greater quantity, merely objectionable from the disagreeable sensation they create through the sense of smell. On the contrary, it is not too much to say that they are the direct, as well as aggravating cause of a large amount of human unhappiness and trouble.

On looking over the bills of mortality, we are amazed at the large proportion of deaths immediately, or distantly, attributable to aërial poisons. Apart from the large number of epidemic complaints, which for the most part take their origin from some of the preventable emanations before referred to, we cannot but be struck with the fearful proportion of deaths by consumption and other chest complaints, which annually deprive us of the fairest and best of our relatives and friends. Diseases of this character are at last developed, but too often clearly produced, by aërial impurities, as shown by the fact of their being common only amongst the permanent inhabitants of large towns and cities, where an impure atmosphere most prevails.

These facts sufficiently testify that we cannot habitually inhale impure air without incurring great risk, and that deteriorated or dirty air cannot be substituted for the pure air of heaven with impunity.

A partial exposure to an unwholesome atmosphere, may, however, often be borne almost with impunity by healthy persons, provided a periodical change to one of a better description can be indulged in. Thus, in the case of that numerous class of men whose occupations necessitate their attendance in the closest parts of cities during a considerable part of the day, good health may be enjoyed when the remainder of their time is spent in a comparatively salubrious atmosphere, such as is generally found in the suburbs of all large towns.

This is chiefly because a supply of good air is most essential during the time of sleep, as it is mostly during the hours spent in this condition that Nature takes the opportunity of repairing, as far as possible, the dilapidations that have taken place during the period of active exertion. The effects of bad air are thus proportionably more detrimental to those who spend the whole of their time in it, than when even a short relief can be had.

The doctrine occasionally promulgated, that an impure atmosphere, or bad air generally, is harmless, and in some cases beneficial, seems to us unworthy of serious discussion. The porportion of deaths in particular districts, upon which such arguments are founded, affords but poor evidence of the ravages of impure air and other destructive agents; but apart from the question of lives literally lost from such causes, we must not forget that a great part of the evil arising from injurious agents generally, as well as the one now in view, especially when aggravated by hard work and hard fare, consists in permanently reducing the standard of health in those who are exposed to them. Such persons, in losing health, lose spirits and energy, and necessarily become unhappy, quarrelsome, or miserable, according to the degree of departure from a natural state of health,—results qualified, of course, by disposition, temperament, &c. These consequences fall most heavily upon the lower orders of society, who are, moreover, most exposed to their influences; since, having few or no resources of an intellectual or refined character, they naturally become exposed to further evils of a moral nature. Although it would be quite out of place for us to trace the moral effects of physical evils, we may yet be allowed to remark, that as many of the failings found amongst the lowest orders of society, are the natural consequences of the wretched condition in which their lives, often for several generations, have been spent, we should not be too severe upon persons so situated, until reasonable and adequate means of amendment are afforded.

CHAPTER VI.

WATER AS A DOMESTIC AND SANITARY AGENT.

INDEPENDENTLY of the many important services which water confers upon us in virtue of its office as one of the principal agents in the system of nature, it also contributes to our comfort and happiness in several minor or rather more commonplace ways.

We may have gathered much respecting water, in the former character, from what has been said in the foregoing chapters; we now, however, propose to treat of water in reference to these minor uses, or, in other words, of water in its more strictly domestic relations.

The uses of water, in relation to personal washing and bathing, in laundry operations, also in cooking, as well as in washing and cleaning generally, need only be mentioned as familiar instances of the exeeding value of water in the operations of everyday life. The properties of water which affect its value for these and other purposes, are matters of some interest, and often of importance, not only as regards household economy, but also as regards our personal health and comfort.

For instance, the quality of water as regards "hardness" or "softness," influences, to a great extent, its value in the majority of the above-mentioned applications. Indeed, so great is the difference in the value between two kinds of water respectively possessing these qualities, that the absence of a supply of soft water, apart from that supplied by the rain, which is the only resource in such cases, is justly considered a great drawback to the convenience of a dwelling-house. Again, the quality of water, as regards its fitness to be used in the direct preparation of beverages, such as tea or coffee, or to be taken in its natural state as a beverage, is a matter of more importance than is commonly supposed.

Of course, if water is palpably bad, *i. e.* of a bad colour, smell, or taste, we instinctively reject it, if better is to be had, and thus avoid any inconvenience or injury it might be capable of inducing. But it not unfrequently happens that the water we use is not bad enough to attract attention in this way, but is quite bad enough to cause much annoyance, and even suffering. It is not too much to say that a great amount of unaccountable ill-health, or even more serious results, are traceable to a defective water-supply.

If we bear in mind the comparatively large quantity of water we take, in some form or other, during the day, the greater part of which is generally furnished from the household source, we can imagine that any appreciable impurity contained in such water has full opportunity to exert any ill effects it may be capable of. When we further learn that a large proportion of the water supplied to dwelling-houses, especially those remote from any regular water-supply, is of a very objectionable character, as we shall presently point out, it will, perhaps, be seen that some attention to the nature of the water used in domestic operations is necessary.

One of the most useful domestic applications of chemistry is in determining the quality of a water-supply; since a definite knowledge of any defect that may exist in the water we are using will often materially assist us in devising a remedy for it.

Before proceeding further, we must briefly describe the more prominent physical properties of water; as it is upon these properties chiefly that its use in relation to domestic operations depends. Such description may not, perhaps, be altogether uninteresting from other points of view.

PHYSICAL PROPERTIES OF WATER.

WATER is often spoken of as a mineral; and although it does not, to uninitiated eyes, appear to have many points in common with flints and stones, yet its place amongst natural objects undoubtedly belongs to the mineral kingdom.

The only strong point of distinction between water and other minerals is its fluidity at comparatively low temperatures, such as prevail in temperate climates, and its comparatively great susceptibility to alteration in form by heat. Fluid water readily changes into a solid, which we call ice, and into a gas, which we call steam; all of which changes take place within a range of 180° of Fahrenheit's thermometer.

Water offers a remarkable exception to a rule very widely followed by the materials of the earth. Nearly all other bodies successively shrink in bulk as they pass from gases to liquids, and from liquids to solids,—a change of state dependent on temperature, which the majority of the materials around us are capable of undergoing, and which, there are reasons for assuming, extends to all the materials of the globe. Water also conforms, in part, to this almost universal rule, but, as above stated, also presents an exception to it. This exception consists in its expanding as it becomes changed into a solid, or into ice. In freezing, water becomes more bulky, and, consequently, lighter, which is the immediate cause of ice being found only on the surface of any mass of still water exposed to a low temperature.

We should not have space, neither would it be altogether in character with our present subject, here to point out the very important natural consequences traceable to this, at first sight, unimportant fact. We need only remark, that upon it probably depends the habitableness of many temperate climates of the globe, which, but for this and some other properties of water, would possess an arctic climate. This singular property of water is often illustrated in a manner unpleasant to householders, by the bursting of water-pipes. The great annoyance often suffered from the flooding by water, on the occasion of a thaw after a hard frost, is the result of the water in the pipes having become larger during its freezing, whereby the pipes are rent at the weakest places. No amount of strength, however, or thickness in the material of the pipes, would protect them from injury by this source, because the water expands with irresistible force, and whatever kind of material contains it while undergoing expansion, must be broken, unless it be of a material capable of yielding to its increase in bulk.

The passage of liquid water into steam takes place at all times from all water exposed to the air. When wet clothes or wet floors are exposed to the air or wind to dry, the water left upon them as damp or moisture passes thus into steam, which diffuses itself through the air. The passage of liquid water into steam depends chiefly on the amount of heat it is exposed to : this is the reason why wet things dry more quickly in summer than in winter.

The boiling away of water over a fire, as from a kettle for instance, is merely a rapid conversion of the water into steam, which, it must be understood, is perfectly invisible, like the air, and must not be confounded with the white vapour produced when steam escapes into the air : this is no longer steam, but finely-divided water.

Under ordinary circumstances, water boils at a fixed temperature; this is 212° of Fahrenheit's thermometer, and is dependent on the weight of air pressing upon its surface, in a manner we need not stop to explain. We remark, however, that as the weight of air diminishes as we rise from the surface of the earth, so does the boiling-point of water and other fluids fall; so that at a great altitude, but not greater than is reached by balloons, we could easily bear our hands in boiling water. A pleasing anecdote, illustrative of this curious fact, is related in Darwin's "Voyage of the *Beagle*." In ascending a high mountain, eggs were taken as provisions to be cooked on the route, and, as a considerable altitude had been reached before these provisions were applied to, the water "refused to cook the eggs," according to the simple conclusion of the guides, in consequence, as they affirmed, of the pot being a new one.

The above-named temperature is only reached when the water is in a state of complete ebullition, or when it actually boils,—a condition essential to the success of many operations in which it is used, but which is often incomprehensible to servant-maids.

Perhaps the most interesting property of water is its power of dissolving certain solids and gases, inasmuch as it is to this property that most of its useful applications are to be referred. Moreover, the difference of quality in the waters of particular districts also depends on this power of water as a solvent.

It must be understood that substances dissolved in water become invisible, provided they are colourless; the water containing them, or the solution, as it is termed, cannot be distinguished by its appearance from pure water.

Thus, when we add sugar to water, it dissolves, and can now accompany the water through the finest channels, no filter or strainer, however fine, being able to separate it from the water. In the same manner, a great many solids are, more or less, soluble in water, to which they impart their properties, and thus make it more or less impure: hence, water is often impure in this manner, though it may be perfectly clear and irreproachable in appearance.

After the above remarks, we need hardly say that filters, as used for domestic purposes, do not remove from water those impurities which are dissolved in it, but only such as are suspended in or mixed with it. As many kinds of natural waters are, however, only objectionable from impurities of this nature, the passing them through a filter is, in some cases, a sufficient means of purification. Moreover, as most waters contain some impurities of this nature, in addition to those that may be dissolved in them, the use of domestic filters is in all cases to be recommended.

The materials commonly used for clarifying water in domestic filters are sand and coarse sandstone, sponge, and charcoal. Whatever substance be used, it acts purely mechanically, as a fine sieve or strainer, the meshes of which are smaller than the solid particles suspended in the water. It is true, charcoal will, in some measure, exert a further purifying effect over water passed through it, as mentioned in a former chapter; but this action of absorbing bad-smelling or otherwise objectionable compounds, is only actively exhibited by charcoal when in a fresh or recently-burned condition: hence, if required to act otherwise than as a fine strainer in filters, it must be constantly renewed.

The solvent action of water above referred to is that upon which a great many of its domestic uses depend, especially those of washing and cleaning generally. This useful property of water is greatly increased by heat (hence the greater value of hot water for cleaning purposes), and in regard to common impurities, also by soap, as we shall presently explain.

Solids which are thus dissolved in water are generally more difficult of separation from it than when merely suspended in it. Although a few such impurities (as those which render water temporarily "hard") may be separated from it by boiling, and in some cases by still simpler means, most of them, as the salts dissolved in sea-water, for instance, can only be separated by evaporating or boiling away the whole of the water; when such salts, not being volatile, are left behind. If we wish to collect the water thus separated, we may do so by bringing it, as steam, in contact with any cold body, which, absorbing the heat, reconverts the steam into water, which will now be free of any solid impurities it may have contained. This process is that of distillation, already referred to, and is resorted to whenever pure water is required. By this process, the dirtiest and most impure water may be purified; even sea-water (to which, however, we must not apply these terms) may be rendered usable by this means. A great many steam-ships are now supplied with an apparatus on this principle, for obtaining the fresh water they require from the steam generated from sea-water.

The above short description of the physical properties of water (the latter more especially) will enable us to perceive that the quality of any natural water is almost wholly dependent on the nature of the materials it comes in contact with. Thus, the purest water will be found in districts where very hard siliceous rocks prevail; for the simple reason that in these rocks there is very little that the water can find to dissolve. This is the case in many of the Scottish lakes,—Loch Katrine, for instance, the water which has lately been brought, at a great expense, to the city of Glasgow. Again, in districts where limestone rocks or chalk-beds prevail, the water will be "hard," from the presence of carbonate of lime dissolved from these rocks, in the manner we shall presently point out.

In districts of an alluvial character, the water is likely to be muddy or discoloured, from the presence of suspended clay, especially after floods. If a spring of water, in its passage towards the surface, happen to meet with a deposit of any soluble material, the water becomes impregnated with a large quantity of this material, and a peculiar kind of water results. In this way the mineral waters are accounted for. The only reason such waters are rare, and that fresh water generally is comparatively uniform, that is, in so far as to allow of its being drunk, in nearly all parts parts of the world, is simply because soluble minerals form but a very small portion of ordinary rocks and soils.

Apart from the general causes of variation in water, as above mentioned, its quality is influenced to a much greater extent by causes of a purely local character, such as the position and construction of the wells in which it is collected, or even of the receptacles in which it is preserved when supplied from a distant source in pipes.

Although London and some other large towns are provided with good water-supplies, a great many even flourishing towns are very badly off in this respect, the nature and quality of the water obtainable being too often a matter of chance. Considering the great importance of a copious supply of water, in a sanitary and every other point of view, and bearing in mind the vast sums spent on much less serviceable undertakings, it is certainly surprising that more has not been done in this country in the way of obtaining good water supplies.

The kinds of water commonly at command for domestic purposes, are rain-water, river-water, and well-water.

Rain-water, as it falls in open districts, is remarkably pure water; indeed, the purest kind of water occurring in Nature. In falling through the air of towns, and especially in flowing over roofs of houses, it, of course, becomes, more or less, contaminated with various impurities; amongst the rest, with the empyreumatic compounds of soot, which confer upon rain-water its unpleasant taste, and render it unfit for the preparation of beverages. These impurities seldom, however, interfere with the natural "softness" of rain-water, which leads to its being so much prized for washing and some other domestic operations, especially in districts where no other source of soft water exists. The softness of rain-water is accounted for by its having had no opportunity of dissolving those matters which render water hard. In all cases, this desirable quality depends on the freedom from any quantity of earthy matter, more commonly lime, in solution.

Spring-water, on the contrary, especially that of limestone districts, is rich in earthy matter, and is, therefore, unsuited, and sometimes wholly unfit for domestic purposes.

The kind of water best suited for domestic use generally, is that furnished by streams and rivers; since this water, although subject to variations from the nature of the district through which it flows, as already pointed out, is generally sufficiently soft for ordinary purposes, while it does not possess the defects of rain-water. The water supplied to London by the large water companies is of this character, most of it being obtained from the New River and the Thames.

The latter river, though at present so much polluted near London, yields excellent water nearer to its source. An idea of the composition of the solid matter discovered in river-water, may be gathered from the following table, exhibiting the composition of the water supplied by two of the London companies:—

THAMES WATER, AS SUPPLIED BY TWO OF THE LONDON WATER COMPANIES.

	Per gallon.	
	Lambeth.	West Middlesex.
Organic matter	1·39	2·08
Silica	·35	·52
Oxide of iron	·21	·46
Carbonate of lime	10·14	9·91
Sulphate of lime	2·15	2·11
Carbonate of magnesia	·59	·72
Chloride of magnesia	·62	·36
Sulphate of potash	·73	·57
Chloride of sodium	·96	1·63
	17·14	18·36
Degree of hardness	13	12·8

This water is filtered on a large scale, through beds of sand, before distribution, in order to remove its mechanical impurities: thus prepared, it constitutes as good a description of water as can be desired for most domestic purposes.

It may, however, be greatly improved for drinking, by filtration before use: the object thus gained, is the removal of animalcules and other impurities which escape the general filtration, or that gain access to it subsequently in the pipes and receptacles through which it flows.

The defect of river-water before alluded to,—viz., its muddiness, or want of transparency, is often a source of annoyance, especially in laundry operations. The particles of clay thus suspended in the water being exceedingly fine, are very difficult of removal by filtration. The plan commonly employed for the removal of this defect, consists in allowing the water to stand for some time in large receptacles, where, being undisturbed, this impurity is slowly deposited.

The water supplied by wells is generally much inferior to that last spoken of. Well-water is, however, of two distinct kinds; viz., that furnished by deep, or Artesian wells, which, reaching natural springs, of course furnish water possessing, more or less, the defects of spring-water. Well-water is, however, more commonly supplied by surface-wells, or wells of no great depth, which derive their water from percolation through the surrounding soil.

The water of surface-wells is often exceedingly impure, from the presence of animal and vegetable matter, which is apt to find its way into wells of this description, from their being injudiciously placed too near the drains of houses, cesspools, stables, and other probable sources of contamination. This evil is, of course, more prevalent in districts where the subsoil is of a gravelly and porous character, but exists, more or less, to a great extent, and is the reason why common well-water is the worst kind that can be used for domestic purposes.

Impurities of this character, including fungous growths, as well as living abominations, are, probably, amongst the worst that occur in water used for domestic purposes; since abundant evidence exists for showing that the habitual use, internally, of water contaminated in this manner, is not only a probable source of ill-health, but also a powerful agent in aggravating maladies arising from other causes.

If a low-lying, dismal-looking house were pointed out to us as a place in which a spell existed against the lives of its inhabitants, the first suggestion that would occur to us would be, to look to the water supply.

The presence of nitrogenized organic matter in water (its most objectionable impurity) is always indicated by a curious circumstance, which furnishes us with an excellent means of ascertaining whether a well be contaminated, or likely to be contaminated, in this manner: we say, likely to be; because it often happens that water becomes objectionable in this way only at particular seasons, as when, by heavy rains, the influx of water is greatly augmented.

The circumstance we allude to is the formation of nitric acid from the oxidation of the nitrogen present in such impurities. Thus, in water that is impure from organic matter of an animal or nitrogenous character, we always find more or less nitric acid, in the shape of nitrate of lime; sometimes other nitrates. On this account alone, such water is objectionable; for, although an occasional dose of nitre might be perfectly harmless, or even beneficial (as it exerts a medicinal effect on the kidneys), it must, of course, have a different effect when taken habitually in tea, coffee, or in comparatively large quantities, such as not unusually occur in bad well-water.

It is probable, however, that the nitrates are the least injurious constituents of such water.

Nitre is more especially formed in this manner in the wells of limestone districts, as the presence of lime facilitates the formation of nitric acid from organic combinations of nitrogen. The formation of nitric acid under these circumstances, proceeds, however, more or less, in the wells of other districts. It must also be understood that small quantities of nitrates are very common in good water, and are objectionable only in larger quantities, or as an indication of the presence of nitrogenized organic matter.

An idea of what constitutes an objectionable quantity of nitric acid in water, and of the composition of ordinary well-water, may, perhaps, be gathered from the subjoined analysis :—

COMPOSITION OF AN UNWHOLESOME WELL-WATER.

	Per gallon.
Solid matter	22·40
Consisting of organic matter	1·04
„ mineral matter	21·36

THE MINERAL MATTER CONTAINED—

Lime	6·50
Magnesia	1·78
Oxide of iron and trace of phosphoric acid	.40
Potash	1·80
Soda	1·10
Chloride of sodium	3·06
Sulphuric acid	2·06
Nitric acid	3·56
Ammonia	·35
Degree of hardness	9

If one quart of the above water be taken per day (in tea or coffee), we should receive into our system as much nitrate as is present in 3½ grains of nitre, or in a week, 23 grains; a very good medical dose.

In this analysis, the bases and acids are given separately, in order that the actual amount of nitric acid may be seen.

APPLICATION OF WATER TO WASHING AND CLEANING.

One of the most important, if not *the* most important, domestic application of water is that of washing and cleaning generally, in conjunction with soap. Thus associated, these agents undoubtedly constitute two of the greatest blessings of civilized life. It is more especially in relation to these uses of water,—that is, in cases where soap is used,—that its quality, as regards "hardness" or "softness," is of most consequence; we therefore now propose to explain more in detail the causes which operate in producing these qualities of water. Before doing so, we must say a few words about soap, as it is chiefly in connection with this substance that these qualities are displayed.

As is well known, soap is obtained by boiling some fatty substance, as tallow, with an alkali, like potash or soda. Under these circumstances, the peculiar and most characteristic property of fats and oils, viz., their total insolubility with water, is lost, and there results a chemical compound, perfectly miscible with water, which we call soap. On agitating with water, we obtain the peculiar adhesive liquid which we call lather, whose invaluable properties allow of its extracting every kind of dirt and impurity from any material that may be brought in intimate contact with it by rubbing or boiling.

The most active constituent of soap is the alkali, *i. e.*, the potash or soda it contains. These substances have already been mentioned in an early part of this work, as forming respectively one of the two constituents in a common group of bodies called salts, which, as before stated, may be regarded as consisting of an acid and a base. When either potash or soda is uncombined with any acid, it possesses, in a high degree, the property termed alkaline; that is to say, it is caustic to the taste, dissolves fats on boiling, and softens and destroys every kind of animal membrane,—a property which gives rise to the slippery sensation experienced on rubbing alkaline liquids between the fingers. These properties of alkalies are entirely removed by union with a strong acid, but only in part, if the acid happen to be a weak one. Thus, in common salt, we have soda combined with muriatic acid, which, being a strong acid, entirely overcomes and conceals all the alkaline properties of the soda. In soap, again, we have the same alkali, soda, combined with a weak acid,—one of the fatty acids spoken of in connection with the fat of meat: hence, in soap, we find the alkaline properties of soda modified to a useful degree; that is to say, its corrosive or solvent power, in regard to animal matters and fat, is reduced sufficiently to allow of its advantageous application to the purposes of washing and cleaning, which, in most cases, essentially consists in dissolving the animal matters of a fatty character, by which all kinds of extraneous substances are attached to the skin or to the fibres of clothes that are dirty.

In washing-soda, again, we have an example of a mild alkali resulting from the combination of a strong alkali (caustic soda) with a weak acid (carbonic acid). We may add that this substance, and also the soda existing in soap, are both prepared from common salt.

White curd soap, which is also the basis of the better kinds of so-called fancy soap, is made of the best tallow and soda. Yellow soap is made of common tallow, rosin, and soda, but with an excess of alkali; that is, more than forms a definite combination with the fatty matter present. This is the reason of yellow soap being more effective for cleaning purposes, but the worst kind for washing the skin; because the large quantity of unsoftened alkali it contains, attacks the skin too violently; which results in the roughness of the skin experienced after washing, and especially after shaving, with yellow soap.

This unpleasant sensation of roughness on the skin is also, in part, due to the lime in hard water. The softest water, as well as the purest soap (white curd soap, or the best Windsor), are not only the most agreeable to use in washing, but are the most calculated to preserve the purity of the skin. On this account, distilled water is valuable for this purpose; but is a luxury that can seldom be indulged in.

The reason why hard water does not act towards soap, in washing, &c., as soft water does, and is, therefore, so much less agreeable and convenient to use, is because the lime, or other earthy material present in hard water, forms an insoluble compound with the soap, in which condition the latter is of no more use than if it were not present.

The compound thus formed between lime and soap is of a definite kind; it is, in fact, a soap, *i. e.* a chemical combination between an alkali (lime) and fatty acid, and is useless to us, merely because it is insoluble. The soap we add to hard water is changed into this insoluble soap as long as any lime is present: hence, we cannot get a lather,—in other words, the soap we add cannot begin to act, until all the lime present is supplied with this definite amount of soap.

Thus, apart from the inconvenience and inefficiency connected with the use of hard water, it also leads to a considerable waste of soap,—a waste proportionate to the amount of lime present in the water, or, in technical parlance, to the degree of hardness. The following analysis is of a very hard water I lately analyzed:—

COMPOSITION OF A VERY HARD WELL-WATER.

		Per gall.
Organic matter		2·76
Mineral matter	83·60	
Consisting of,—		
Carbonate of lime		6·05
Sulphate of lime		27·88
Sulphate of magnesia		20·93
Carbonate of magnesia		8·49
Sulphate of soda		8·16
Sulphate of potash		2·64
Chloride of sodium		8·41
Oxide of iron, with trace of phosphoric aicid		·72
Soluble silica		·32
Nitric acid		trace
		86·36
Carbonic acid gas		4·51
Degree of hardness		55
After boiling		49

The quantity of soap thus consumed by hard water before the soap used can begin to exert its detergent effects, has been found to be about ten grains of white soap (more of yellow) for every grain of carbonate of lime; so that, in the case of the above water, 605 grains, or more than 1¼ oz. of yellow soap would be wasted for every gallon of water used; or, in other words, this quantity of soap per gallon would be required over and above what we should want if soft water were used.

But this is not the only objection that attends the use of hard water in laundry operations. The insoluble compound above mentioned is apt to separate in the fibres of the clothes being washed, after the manner of a dye, and, by fixing some of the colouring-matter, gives rise to stains, or a "bad colour." This failing is the more undesirable, from its affording an excuse for the employment of bleaching-powder, &c., to which laundresses are always too ready to resort to save themselves trouble. We need hardly say, that the use of these substances tends to rot the clothes, particularly the sewing threads. The action of these substances depends, in fact, on the destructive tendency of chlorine and its compounds towards all organic matter, as before referred to. A brief exposure to its action results only in the destruction of the colouring-matter of stains, &c., and a consequent bleaching; but by a longer exposure, the fibres of the fabrics are themselves attacked.

Before passing on to the means commonly employed for softening water, we must inquire more particularly into the cause of its hardness. We have said that this property is due to the water containing lime and other earthy salts in solution. We have now to account for the presence of these substances in water, since, under ordinary circumstances, they are insoluble in this fluid. Hard water is of two kinds. The hardness is said to be temporary when it disappears after boiling, or by the application of still more simple remedies, presently to be described. In these cases the lime is present in the water as bicarbonate of lime, or, in other words, carbonate of lime or chalk dissolved by the agency of carbonic acid gas. Hard water is, however, not unfrequently met with, that refuses to yield to these comparatively simple remedies, and is, hence, a much more objectionable description of water: such water is said to be permanently hard, and owes its peculiarity to the fact of the lime being present in the water as sulphate of lime, or plaster of Paris.

If we place a little of this latter substance in soft water and allow it to soak for a few days, we shall find that the water has become "hard," a result we can, in this case, easily account for, as plaster of Paris is, to a small extent, soluble in water; one part of the salt requiring about 500 parts of water to dissolve it. Masses of this mineral (termed gypsum) are occasionally found in nature, as, for instance, there is an entire mountain near Paris composed of it (hence the term, plaster of Paris); but in smaller quantities it is very widely diffused in nature. Nearly all waters contain more or less of this substance, and if a spring of water finds its way through a deposit containing much of it, we then get a water particularly rich in this material, and therefore permanently hard.

The case is somewhat more complicated with waters that are temporarily hard. In these waters the lime is present as carbonate of lime, or chalk; a compound which is known to be by itself insoluble in water.

If we repeat the foregoing experiment, using chalk instead of gypsum, we shall find that no perceptible change in the quality of the water results. How, then, it may be asked, does the chalk become soluble? This may be shown by a pretty experiment.

If we pass carbonic acid gas* through some lime-water, made as directed at p. 19, and contained in a wine-glass or other vessel, as shown in the adjoining sketch, a white sediment soon forms, which is carbonate of lime, or chalk. The formation of this substance increases up to a certain point; if, however, we still continue to pass the gas through the mixture, the white sediment again dissolves, forming a clear liquid. In this liquid the lime exists in the same condition as it does in the water now under consideration. If we boil a little of this liquid, the white sediment again makes its appearance, owing to the carbonic acid gas, which kept it in solution, being thus expelled.

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* Carbonic acid gas is easily prepared for this purpose by placing in a bottle of any description, some fragments of marble. The

In the same manner iron and some other impurities found in water are rendered soluble by the carbonic acid also present, and may be separated, in many cases, by boiling in the same manner. Hard water from any natural source, boiled as in the above experiment, will generally be found to lose its transparency, and deposit carbonate of lime, either as a sediment, if the quantity of lime is large, or as minute crystals, which adhere to the sides of the vessel, and are somewhat difficult of removal by mechanical means. It is carbonate of lime separated in this manner which forms the incrustation in tea-kettles and steam-boilers; in the latter vessels constituting a source of considerable inconvenience. Such deposits may be entirely removed, on a small scale, by dilute muriatic acid, which decomposes the carbonate of lime.

The above experiment suggests a means of softening water which is hard from carbonate of lime, or whose hardness is temporary. If we are prepared to boil water of that character for two or three hours, and allow it to stand till cold, the greater part of the lime may be separated, and a much softer water be obtained.

This result does not happen when the water contains sulphate of lime, since this salt of lime is as soluble in hot as in cold water: hence the term "permanently hard" as applied to water of this kind. The mode of

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bottle is to be closed with a tight-fitting and sound cork, through which a bent tube passes. This tube is to be bent at two right angles, and may be made of the thin glass tubing procurable at druggists' shops; being easily bent over a lamp or gas-burner; or it may be made of the small pewter tubing used by gas-fitters. The cork can be bored to receive this tube with a hot skewer or clay tobacco-pipe stem. In preparing the gas, some dilute muriatic acid must be poured over the marble, until a brisk effervescence is set up; when the bottle, being closed with its cork and bent tube, the gas may be conducted by the latter where desired.

softening water above referred to, although obviously inadmissible as a constant remedy, is yet useful for softening the water required for particular purposes, as for laundry operations, &c.

A similar result may be partially obtained by exposing such water, for a length of time, to the air in shallow vessels, when part of the carbonic acid gas escapes, and some of the carbonate of lime separates, but much less effectually than by an elevated temperature. In this way we can account for the comparative softness of the water of streams or rivers, though, perhaps, in the first instance, supplied by springs of hard water: during the prolonged exposure and admixture with air, the lime separates as above.

Another mode of softening water of this description consists in the addition of lime to it. This process, though, at first sight, difficult to comprehend, inasmuch as lime is, as we have seen, the general cause of hardness, is easily understood, after having witnessed the experiment described on the preceding page.

The process is well known as Dr. Clark's patent, and is extensively adopted for softening water on a large scale, by several of the large water-companies. To understand this process, we must call to memory that the lime in hard water (temporary) is present as bicarbonate of lime; *i. e.*, every part of lime has two parts of carbonic acid gas combined with it, in which condition only is it soluble in water. The processes above named have for their object the expulsion of this second quality of carbonic acid; but it may also be removed by adding more lime,—that is, caustic lime, which may be regarded as lime, *without any carbonic acid.* This, in taking up the second quantity of carbonic acid, not only becomes carbonate of lime itself, but also reduces the original soluble bicarbonate to the same condition; so that all the lime now becomes insoluble carbonate of lime, which settles on standing.

The adoption of this process on a small scale is scarcely practicable, for the obvious reason that unless the lime be added with great care, the water is made much harder instead of softer. The proper quantity of lime can only be found by careful experiments; the chief of which consists in determining the degree of "hardness," as it is termed, or on the extent of hardness, as compared with some standard.

In all analyses of water supplied for domestic purposes, the extent of hardness should be stated in degrees; the number of degrees generally corresponds pretty closely with the number of grains of earthy salts per gallon.

The preceding modes of softening water are, as already stated, inapplicable to water rendered hard by sulphate of lime. In these cases, the softening must be effected by means of soda or pearl-ash.* The effect of these salts, especially on boiling, is to convert the sulphate of lime into carbonate of lime, which, being insoluble, is now capable of subsidence, as in the foregoing instances. The advantage gained by adding soda to water, even when not naturally hard, during washing, is due to its softening the water more completely than can be effected by other materials, since the small quantity of sulphate of lime generally present in the best of water, as already mentioned, is by this means precipitated.

In softening water in comparatively small quantities for special purposes, as for laundry operations, by the addition of soda, or by the still superior method we have mentioned, it is advisable to allow the water to stand until cold, before using, and to draw it off from the sediment. By this means, a much purer water is obtained, and the linen washed is likely to be of a better colour than if the soda be added during the washing.

In drawing off water softened by this means, or in the still simpler process mentioned in the preceding page, as well as in numerous other domestic operations, we may employ with advantage the siphon, an instrument but little known in households generally, but of wide and indispensable application in laboratories, and for numberless technical processes. It is especially serviceable when it is desired to draw off a liquid from any sediment without disturbing it, or to transfer a liquid from one vessel to another without lifting it. The siphon consists merely of a tube bent at an acute angle, or like a V; one leg should, however, be a little longer than the other. It may be made of any convenient material,—of glass tube, which may be bent over a lamp, or gutta percha, or, what

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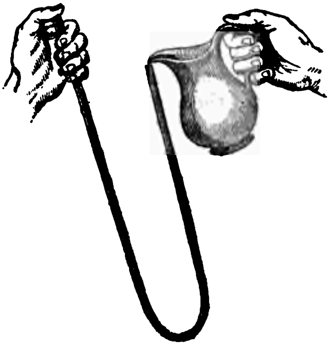
* The efficacy of soda is greatly increased, in washing, &c., by dissolving in water with a handful of quick-lime, and allowing the liquid to stand till clear. The carbonate of soda (washing soda) is by this means converted into caustic soda (lye).



is more convenient, pewter gas-tubing. In using it, all that is necessary, is to pour water into it until full, when, by placing the thumb on the mouth of the longer limb, the instrument may be held with the bend upwards without the water flowing out.* The shorter limb is now placed in the liquid to be drawn off, when, on removing the thumb from the other limb, hanging over the side of the vessel, the water flows off through the latter, until none is left; it may, however, be stopped, if desired, by raising the short leg out of the liquid.

In addition to the disadvantages connected with the use of hard water, in cases where soap is used, its inferiority is shown in several other ways; as in making tea, cooking, and especially boiling vegetables.

In the former case, a much longer maceration with the tea is requisite, and this often extracts nasty-tasting principles from the tea, which are avoided in the more speedy performance of the process.

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* If the tube be of large size, it may be necessary also to close the shorter limb with the finger, until placed in the liquid. Half-inch to three-quater-inch bore is a good-sized siphon for general purposes. The usefulness of this instrument is greatly increased by a stopcock or tap at the end of the longer limb.

Again, in boiling vegetables, hard water is inapplicable, since the sulphate of lime tends to form an insoluble compound with the legumine of the vegetables, and interferes with their proper cooking.

RECEPTACLES FOR WATER.

The wholesomeness of water is much influenced by the kind and condition of the receptacles provided for it. All cisterns or other vessels used for this purpose should be periodically cleaned at moderate intervals, so as to retard as much as possible the growth of animal and vegetable impurities. They should also be carefully closed, so as to exclude dust and dirt, but not so completely as to exclude air.

Cisterns, and other holders of water intended for general use, should, if possible, be placed in some part of the building where the air is reasonably good, and not in any hole or corner, where most out of the way. An unfortunate advantage, on the score of convenience, leads to a very objectionable arrangement found in a great many houses; viz., that of placing the cistern for water in close proximity, and often immediately over, the water-closet.

Water is extremely susceptible to contamination from the absorption of bad smells or objectionable emanations of every kind, as is shown by the service it renders in hastening the removal of the smell of paint when it is exposed with this object in places that have been recently painted. For this reason it is obviously unwise to expose water to deterioration in this manner, if it can be avoided.

Water supplied through leaden pipes, and preserved in leaden cisterns, is sometimes rendered unwholesome by contamination with this metal. The mischief likely to arise from this source has, no doubt, been occasionally overrated; yet there can be no doubt that the water daily consumed by families is occasionally tainted with lead to an extent sufficient to injure health.

Notwithstanding that the quantity of lead, or rather of the objectionable compounds of this metal, likely to occur in water from this source can seldom be otherwise than exceedingly small, indeed, quite small enough to be laughed at, were it swallowed only on one occasion, or even for a short time, it becomes invested with more importance if we recollect that its action may extend over an indefinite period. Metallic poisons of this description are never so effective as when administered in small quantities for a length of time; a fact that applies especially to the metal in question. We do not mean to say that persons are often killed by this means; but we are apt to forget that a poisonous agent may produce much mischief in the shape of inexplicable ill-health, or otherwise, without actually causing death.

On the score of health, lead is about the worst material that could have been chosen for containing and conveying the water required for domestic use; but its many great advantages, in a mechanical point of view, have rendered its use for this purpose too extensive to be easily put aside for any more wholesome material.

If a piece of metallic lead with a clean surface be placed in soft water for a day or two, it becomes covered with a loose coating of white oxide or hydrate of lead, which is sufficiently soluble to render such water highly injurious, if not poisonous. If old lead be used, or rather lead covered by its ordinary grey oxide, but a slight corrosion only takes place. Thus we perceive that the effects of lead in regard to water are chiefly to be guarded against when new. Again, such corrosion is greatest in proportion to the softness of the water,—distilled water being the most active, rain-water next, and hard water scarcely at all. This is because the soluble salts of sulphuric acid and carbonic acid present in hard water exert a protecting influence, by forming with lead insoluble compounds, which, being deposited on the surface of the lead, prevent further action. Were it not for this natural safeguard, we should suffer to a much greater extent from this source than we do.

It should be mentioned, however, that the conditions under which lead is dissolved by water are not clearly understood, since even hard waters occasionally have been impregnated with lead in a manner that at present cannot be satisfactorily accounted for. It is found that the presence of organic matter in water, especially that of animal origin, and nitrates, favour this corrosive action: hence we perceive a further objection to the presence of these impurities, in addition to those already glanced at. Again, the presence of two kinds of metals, employed as solder or otherwise, is also found to expedite the corrosion of the lead in certain cases, an action probably arising from a feeble galvanic action always set up when two dissimilar metals are immersed in water containing salts.

Water containing an unusual quantity of common salt is also liable to become impregnated with lead. It has lately been found that the rain-water collected from the leaden roofs of lighthouses, or other buildings adjacent to the sea, often contains lead to an injurious extent; a circumstance that can be clearly accounted for by the fact that common salt, or chloride of sodium, is easily changed in the presence of lead into chloride of lead, a compound sufficiently soluble in water to render it objectionable in this way. The remedy suggested by Mr. Faraday, by whom this matter was brought to notice, is to place some chalk in the receptacles where such water is preserved. In adopting this remedy, it would seem to be necessary to filter the water before using it, as the carbonate of lead thus formed is one of the most objectionable constituents of lead when received into the system.

PERSONAL USES OF WATER.

The action of water and soap on our own skin is very analogous to what takes place in their inferior appliances, as above referred to. The soap we use in personal washing, not only dissolves the oily products of the perspiration by means of which various extraneous matters become attached to the surface, but it also dissolves a very thin stratum of the skin itself; a result that still further facilitates the removal of foreign materials.

This latter action is, however, in no way objectionable, unless carried too far (as by the use of the coarser descriptions of soap already spoken of); since a constant degradation takes place from the surface of the skin, in common with every other part of the body; the results of which, unless periodically removed by the above means, or others, quickly impede the functions of this most important organ.

The action of water on the skin generally is in part physiological, and in part chemical; its good effects being attributable not only to the tonic action on the nerves, when cold water is used, and the equally important stimulative action of the subsequent towel; but also to the opening and cleansing of the pores, whereby the materials dealt with by the skin are allowed a freer action.

We have already stated that the skin generally, in addition to its other uses (see page 173), is one of the excreting organs of the system, and that, if this function be not encouraged, the general economy is more or less interfered with. We may now add, for the credit of water as a remedial agent, that by a careful attention to, or cultivation of the skin, so to speak, other feeble organs may be relieved of their work, and thus afforded opportunity of regaining strength and vigour.

The value of water in largely contributing to a healthy system through the skin, is now fully recognized by most cultivated persons of the present age (in this country), which, amongst other evidences of advancement, is marked by a morre liberal use of water externally.

It is a common mistake to suppose that the benefit derivable from water in this manner depends on its being cold, and that unless it can be borne in this condition, its daily use must be avoided. A consideration of the foregoing facts will show this is by no means true; since, although cold water, *i. e.* water of the temperature of the air, is in the best condition that it can be in for use by healthy persons; its use, in the same condition, is often wholly inadmissible, not only for invalids, but for others not altogether robust; but all of whom, with scarcely an exception, would be proportionably benefitted by a daily bath,—that is, sponge-bathing with water of a temperature suited to their strength. Or even supposing such a case possible, that water in any shape could not be used, we might still resort with undoubted advantage to the expedient adopted by Smike and his companions at Do-the-boys Hall, when the pump was frozen; namely, a dry polish.

Of those kinds of water suited for bathing, the best is undoubtedly, for general purposes, sea-water. Although other agencies than sea-water co-operate in bringing about the well-known beneficial results of sea-bathing, yet a considerable share of these good effects must be put to the credit of the peculiar character of the water, as chiefly determined by the various salts it holds in solution.

The solids which allow of detection in sea-water, as also their relative quantity, are as follows:—

AVERAGE COMPOSITION OF SEA-WATER.

	Grs. per gall.
Common salt	1767 (437½ grs. = 1 oz. avoird.)
Chloride of potassium	29
Chloride of magnesium	201
Chloride of calcium	21
Sulphate of lime	115
Sulphate of magnesia	158
Carbonate of lime	14
Carbonate of magnesia	10
Iodine, bromine, ammonia, &c.	traces
	2315 = about 5¼ oz.

Of these solids, as is well known, the chief is common salt; and the prodigious quantity of this substance occurring in the sea, can hardly fail to excite our astonishment, if we reflect on the vast quantity of water belonging to our globe, and the very great proportion of salt this holds in solution. By the above table, we perceive that a gallon of sea-water contains about 5¼ oz. of salt; from which a simple calculation shows us, that a cubic yard of sea-water contains about 42 lbs. of common salt, while a cubic mile of sea-water, which is absolutely nothing in comparison with the bulk of the sea, would contain the astounding quantity of 105,558,300 tons of salt. Thus we perceive that common salt, though a somewhat rare constituent of dry land, is one of the most abundant minerals of our planet.

We find in sea-water certain salts but very sparingly present in other natural waters. Of these materials the most interesting are iodine and bromine, two very curious bodies, which occur in sea-water as salts analogous to common salt. Their quantity is, however, very minute, and would probably never have been suspected to exist there, but for the fact of certain marine plants having the power of extracting the minute quantities of these elements existing in sea-water, and collecting them in their tissues; just as land plants have of extracting certain bodies they require from the soil.

Both of these elements, and also their compounds to a less extent, possess a peculiar and not disagreeable odour, resembling somewhat the smell of seaweeds and the sea—a smell probably in part due to the presence of these bodies.

Iodine in a separate state is a dark-coloured flaky solid, of a metallic appearance, which, on contact with the skin, stains it brown. Its most peculiar property is that of being easily converted by heat into a heavy gas, of a beautiful violet-colour, from the Greek name of which its name is derived.

Bromine resembles iodine in many of its qualities; it is, however, much more volatile, and though generally preserved as a deep red liquid, it shows a great tendency to fly off as gas. Both this and the preceding element, and their compounds, the bromides and iodides, have a powerful effect on our internal economy. Judiciously employed, they supply invaluable remedies for certain diseases of the skin, and other complaints.

Another interesting property of sea-water is its non-liability, compared with fresh water, to induce that disturbance of our system known as "cold." Most persons have experienced that sea-water is not nearly so likely to produce this unpleasant effect as fresh water is.

The salts in sea-water are no doubt the immediate cause of this peculiarity; they probably modify the ordinary effects of water when kept in contact with the skin; under which circumstances it is now admitted to be a potent agent for good, as well as harm.

WATER AS "DAMP."

This matter leads us to say a few words about water in the character of Damp or Moisture.

It is extraordinary what a large quantity of water may exist in certain objects without exhibiting any visible evidence of its presence.

Thus, a piece of limestone (Bath oolite), after exposure to rain, fully soaked, was found to contain, even after all visible water had dried from its surface, one-seventh of its weight of water. A brick (common stock-brick) under the same circumstances was found to contain about one-ninth of its weight of water.

Even dry powders, such as flour, &c., contain as much as 15 per cent. of water. This water is altogether distinct from that which occurs so abundantly in living animal and vegetable products, and which we have called water of constitution. The water held in this manner in the substance of porous bodies, as in the former instance, is called hygroscopic water.

More than a small quantity of water, either in this condition or as perceptible moisture, about or upon us, that is, in our dwellings, clothing, and bedding, is known to be an undisguised enemy to health. No doubt one of the chief causes of the injurious effects of water in this manner arises from the great amount of heat it withdraws from us under these circumstances by its evaporation, which the system is unable to sustain with impunity; but there is probably a more direct action on the nerves through the skin, as hinted in the preceding page.

Entire districts are known to vary much in the amount of mositure pervading them, especially in the winter season, when any defective drainage becomes most apparent. The character of districts in this respect depends mainly on the nature of the formation on which they rest, localities situated on clay-beds being notoriously damp, and comparatively unhealthy; while the most salubrious neighbourhoods are, as a rule, always situated on gravelly or otherwise porous subsoils. The local variations of climate are, in fact, almost determined by the amount of moisture retained by the soil.

In nearly all situations, however, an undue quantity of water is liable to accumulate in dwelling-houses, unless provided against by artificial drainage. An effective means of removing and conveying away all extraneous water constitutes the most essential condition of a wholesome dwelling-house; and too much care can hardly be bestowed upon this matter in the planning and building of any kind of erection, whether for man or beast.

Bricks are better conductors of damp, so to speak, than stone. Stone takes up more water than brick, but less readily; it also parts with water much less quickly than brick.

In all good houses built of stone, this defect is provided against by lining the dwelling-rooms with brick. The deposit of dew, and sometimes of actual streams of water, on the internal walls of buildings, on the occurrence of a sudden change from cold weather to warm, strikingly illustrates the difference of quality in the materials of walls, it being more abundantly deposited on stone walls than upon brick ones; indeed, is rarely perceptible on the latter. This deposition of water is due to the condensation of the steam contained in the warm air by the cold wall, just as the steam in the air we expire becomes condensed if we breathe on a cold glass. A similar phenomenon more freqnently takes place on our windows internally, when the external air is much colder than the air of the room, and externally, when the outer air is warmer than the room, as sometimes happens in sudden thaws.

New houses are notoriously, at first, damp, and require several months' drying before they can be safely inhabited. This must necessarily be the case, from the large quantity of water used in their erection, in the shape of mortar, plaster, &c. Until this water has evaporated, the place will, of course, be perceptibly damp; but even after this period, an objectionable amount of water may be found when they come to be inhabited. This is, because a good deal of the water used in building becomes fixed as hydrates of lime, or definite combinations of water with lime. Some of these hydrates are very permanent, and remain as part of the mortar while it lasts; but others are easily decomposed when carbonic acid gas is present, which the lime takes in preference. The water is thus liberated from apparently dry walls when they are exposed to carbonic acid from the breath or otherwise. On this account, a good way of drying new rooms is by means of charcoal fires.

The last character water assumes previous to its dismissal from our dwellings, is that of drainage and sewage. Not the least of the blessings conferred upon us in water, is that of its affording the means of getting rid of every kind of solid or liquid material which, having performed its office in our service, is of no further use in the same way, and requires to be speedily removed from the vicinity of our abodes.

It is in the character of sewage that water troubles so many wise heads, and costs so much money to be got rid of; the disposal of sewage in a complete and effective manner being one of the greatest difficulties which civic authorities have to contend with, and at present remains a problem only partially solved.

Even the most successful efforts in this direction, at best accomplish but the removal of the objectionable material from our towns and cities, without regard to its subsequent destination. We should not forget, however, that sewage, although so repulsive, yet contains the elements of future supplies of food: hence, no system for dealing with sewage will be complete unless it embraces not only the removal of these matters without offence, but allows of their being returned to the laboratory of Nature, there to begin again the course allotted to them.

CHAPTER VII.

FIRE, IN RELATION TO ITS COMMON USES.

Amongst the characteristic endowments which, from time to time, have been suggested to distinguish man from the inferior animals, is that of being able to call into existence the wonderful agent, Fire. Certainly, man, *i. e.* civilized mankind, would be but poor creatures without it.

Although we no longer confer upon fire the title of an element, yet, in regard to its nature generally, as well as to the comparatively minor affairs of domestic life, it holds a position in no way subordinate, but rather superior, to any of the elements we have had occasion to speak of in the preceding pages. We say superior, because fire may be regarded as one of the forces or agents which help to determine the movements of the ponderable elements of the earth.

Much might be said in praise of fire: how it is, directly or indirectly, connected with almost every branch of human industry; how indispensable it is in the preparation and manufacture of nearly all the numberless necessaries, comforts, and appliances of civilized life; and how, through the agency of machinery, it gives rise to a vast proportion of our national wealth and general prosperity.

Amongst the numberless uses to which men apply fire, not the least important,—at all events, in this and other climates where winter comes, at least, once a year,—is its use in the production of artificial warmth; while, perhaps, a still more important application is to the production of artificial light; all the sources of light commonly used, being but modifications of fire supplied from various sources.

It is chiefly in relation to these two uses of fire, that we shall speak of it in the following pages; although its connection with other domestic applications may be briefly mentioned incidentally.

Being so familiar with fire, both as a source of heat and light, few of us ever bestow a thought upon its nature, or if we do, it is mostly in the spirit of the proverb, "that fire is a useful servant, but a terrible master." Yet fire is, in truth, a most wonderful thing; certainly, one of the most curious and interesting phenomena presented to us.

ORIGIN OF FIRE.

Under the above common term we include, for the present, heat, warmth, caloric, phlogiston, and all other terms which, at different times, have been used to designate that agent, principle, or modification of force, which, in a concentrated state, constitutes fire. Of the philosophy of this phenomenon little is at present known; the following remarks may, perhaps, help us to form some idea of its nature and origin.

During the growth of plants, certain materials of the soil, of water, and of the air, become joined together, and built up into the compounds we have called organic, and from which all food, as we have seen, has been derived. It may now be added, that such organic compounds are also the direct or the remote sources whence every kind of fuel and light-giving material commonly employed is derived.

As the growth of plants, and consequent formation of organic products, take place only during daylight, and vigorously only during direct sunshine, we conclude that sunshine is the direct agent whereby the production of these compounds is brought about. But we may go further than this, and assume that the sunshine, or parts of it, actually become fixed and stored up in the compounds themselves, just as do their ponderable elements, in the manner already glanced at. If this be the case, we might expect to find such sunshine, warmth, or light (for we know the light of the sun to consist of several kinds of light; that is, of rays which give warmth, rays which induce chemical action, as well as those which give rise to the phenomenon of light), liberated again on the breaking up of these compounds, just as the ponderable elements are liberated under similar circumstances. This is in a measure true; since, whenever organic compounds suffer destruction in any of the modes to which they are liable, heat or warmth is always an accompaniment of the products arising from these ponderable elements. If the destruction of organic compounds takes place slowly, as in the process of decay, the heat liberated is hardly perceptible, because it is conducted away as fast as it is formed; but, in the somewhat quicker process of fermentation or putrefaction, as in dungheaps and occasionally in haystacks, it becomes apparent, while, if the destruction of the organic compounds proceeds rapidly, or, in other words, their elements separate under peculiarly favourable circumstances, then we get fire as well as heat, which is merely a rapid and energetic liberation of that heat which is liberated more slowly in the preceding instances.

Thus we may regard all the warmth, heat, power, and light obtained from fuel of every kind, including coal (which is merely the vegetable products of a past age), as having been derived, in the first instance, from the one great source of heat and light,—sunlight.

Whether we regard the sunlight as actually stored up in these compounds, or that this agent merely converts them into a form in which they are capable of giving rise to the phenomenon by their oxidation, matters little; since neither of these views—nor any other, in fact—is capable of clearly explaining the origin of fire. All we can say of it is, that it is modified chemical affinity.

Whatever theory we may adopt in explanation of the question of heat or fire, the process of burning or combustion is commonly one of rapid oxidation; that is, energetic union between certain elements of the burning substance and free oxygen, in all common cases, supplied from the air. In order to make this matter clearly intelligible, the chemistry of the process must now be described more in detail.

CHEMISTRY OF COMBUSTION.

If a piece of paper is set fire to, the greater part is consumed with flame, leaving a crumpled black residue behind. If we further throw this black residue on the fire, it also burns away, leaving nothing but a little ash. This ash is mineral matter, which, in the present case, we need not trouble about. That portion which burns away must obviously consist of materials capable of being changed into invisible gases; since the common, though thoughtless conclusion, that the paper has been annihilated by burning, can hardly be entertained by any educated person of the present day. The materials of the paper, or any similar example, have been simply changed into invisible gases, sometimes with a little smoke (which consist of minute globules of incompletely-burned products). Not one particle, however, of the materials consumed in the burning has been lost or destroyed; they have simply taken another shape, and can even, by suitable means, be collected and weighed in these new forms; when their weight will be precisely the same as before the transformation.

The materials which thus pass off invisibly from paper, and indeed nearly every kind of inflammable material of a similar nature, during their burning, are hydrogen and carbon, the prevailing constituents of all such substances; and the same elements, it will be remembered, which take so important a share in relation to the components of food, and to the process of respiration, which, we may remark, is somewhat analogous to the process now under consideration.

Carbon and hydrogen are the only essential fundamental components of all kinds of fuel and light-giving material commonly used. Carbon often occurs in fuel in a separate state, sometimes nearly pure, as in charcoal, which offers a good illustration of the physical character of this element in its commonest condition, and also of its mode of combustion. Carbon burns either with a solid combustion, as we perceive in the glowing of a small charcoal fire, or with a lambent flame, as we see over large coke and charcoal fires: this flame arises from the formation of an intermediate product, the carbonic oxide already noticed.

Hydrogen, in a free state, is an invisible gas, remarkable for its extreme lightness; bubbles of it are pushed upwards through the air, as corks or other light bodies are in water. Hydrogen gas burns with an intense heat and with flame,—the only way in which gases can burn under ordinary circumstances. The great heat produced by a flame of hydrogen gas appears the more remarkable to persons unaccustomed to chemical phenomena, from the fact of this gas being always produced from water, commonly regarded as the direct antagonist to fire. The very curious phenomenon of flame is the characteristic accompaniment of the combustion of aëriform bodies.

Hydrogen, unlike carbon, seldom or never occurs in any fuel except coal-gas (and there in small quantity), in a free state, but mostly combined with carbon in some of the numerous "hydrocarbons," *i. e.*, definite combinations of these two elements; of which tallow, oil, gas, and even wood and coal, may be regarded as consisting of.

The above two elements, which we may characterize as the two common combustible elements, being the essential constituents of all fuel and light-giving materials, their proportion determines, for the most part, the commercial value of these articles. The relative proportion of carbon and hydrogen also determines their fitness for special purposes, according to the principles we shall presently explain.

In the instances of combustion above cited, and, indeed, in almost all cases where flame is produced, the hydrogen, with a little of the carbon, first burns, while the carbon, being less combustible, *i. e.* having less inclination for oxygen, is left till later. We notice this in a coal fire; the flames are produced from coals recently put on the fire, or which, by stirring, have been recently brought in contact with a strong heat: but, long after the yellow flame has ceased, the coal continues to burn with the solid combustion above spoken of.

The invisible gases into which candles, oil, &c., become changed, so as to allow of their disappearing in the atmosphere of a room, and which allow of tons of coals being carried up our chimneys, in a similar manner, are combinations of the above-named constituents of these materials with the oxygen of the air, and have been already sufficiently described in a previous chapter, under the names of carbonic acid and water. We may regard the process of combustion as one in which the invisible but all-important oxygen of the air dissolves or takes up into itself the carbon and hydrogen of the burning bodies, and imparting to them its own volatility and invisibility, carries them bodily away; thus accounting for the apparent destruction of inflammable materials by fire.

We have, on former occasions, had to call attention to the extreme avidity with which the free oxygen of the air combines with all bodies that are unprotected from its influence; and we have remarked that the immediate causes of Fermentation, Putrefaction, and Decay have their origin in this inclination, if the term may be used, of oxygen to return to its inactive, passive condition, such as it becomes changed into by any of these processes. From what has been said in the preceding passages, it will be seen that the process of burning, or combustion, is of a similar nature, and has its origin in the same immediate cause.

Combustion is supported, or, in other words, the fire we apply to unconsumed fuel is maintained and fed, from the latter, as follows:—The great avidity of oxygen for hydrogen and carbon, or for their combustible compounds, is only exhibited when the latter are red-hot; hence, in lighting unconsumed fuel, we bring a part of it to this condition, when it immediately begins to be consumed by oxygen, and in so doing liberates sufficient heat to raise fresh portions of fuel to their combining temperature; these, in their turn, prepare new quantities, and so on, the process being continuous while the fuel lasts. Heat is produced in this and all other cases by chemical action, and always corresponds in quantity with the intensity of the chemical action.

But, besides that portion of the fuel which takes part in the actual combustion, a considerable portion of it is volatilized, in an incompletely burned state, as smoke. Smoke consists of "intermediate products," or of fuel whose passage through the successive stages of oxidation towards the ultimate products of combustion, has been interrupted; or we may regard it as a portion of fuel which has not been sufficiently heated to allow of it getting enough oxygen to convert it into carbonic acid and water: hence, if the fuel abound in carbon, as in coal, a great deal of the separated carbon is carried away mechanically as soot.

In a perfect combustion, as in a well-constructed lamp, for instance, no visible products of combustion pass off, the whole of the oil being converted into the legitimate products of combustion—carbonic acid and water.

The different degrees of inflammability in fuel depend on the readiness with which they can be raised to the self-supporting point; and this, again, depends much upon the mechanical condition as regards extent of surface. It is only by means of some easily-combustible fuel, such as paper, shavings, &c., and then wood, that we are enabled to kindle the more stubborn fuel, coal; yet this gets on perfectly well when the conditions for its combustion are once established.

The heat derived from fuel in the process of combustion depends mainly on the amount of it completely consumed: hence, we must regard that portion of it converted into smoke as wasted.

Again, when fire is employed as a source of light, the incomplete combustion of the fuel is still more objectionable, as, in this case, the smoke, &c., if formed, mixes with the air we breathe; and such products are, to say the least, more unpleasant than the legitimate products of combustion. Thus, in the construction of lamps, fireplaces, &c., the chief object to be had in view should be to render the combustion as perfect as possible.

The mode of insuring this has been attained in the case of lamps, gas-burners, and other sources of light, many of which at present approach as near perfection in this respect as we can conceive it possible. The same cannot be said of the means we employ for generating heat from fuel, the construction of our fireplaces, furnaces, &c., being, as a rule, very faulty in this respect. At the same time, excellent contrivances exist for saving the fuel commonly wasted as smoke, but are not likely to be extensively adopted, except where compulsory, at the present low price of coal; especially, as in some cases the quantity of fuel thus wasted, is more than compensated for by other advantages. The bearings of this matter, on a sanitary point of view, have been already discussed.

The chief condition necessary for the proper combustion of fuel is a copious supply of air; since the heat generated is chiefly determined by the quantity of oxygen supplied to it. Thus, if by any means we increase the supply of air, and consequently of oxygen, to a fire, the more brightly and fiercer it burns.

In the simplest way of urging a fire by means of a pair of bellows, we supply the fuel with more oxygen, and hence have a brighter and more rapid combustion. It must be understood, however, that any increase of heat obtained by an artificial supply of air is still at the expense of the fuel, which is merely burnt out sooner. A given quantity of fuel can only produce a definite amount of heat; so that the only advantage gained by an increased supply of air, is a greater quantity of heat in a given time.

By forcing air through a fire by some mechanical means, on this principle, we may obtain almost any degree of heat. It is only by such means, indeed, that we are enabled to get fires strong enough to perform many of the technical purposes to which fire is applied; as, for instance, the smelting of iron from its ores.

A simpler and more commonly employed mode of increasing the supply of air to a fire, where strong heat is desired, is by taking advantage of the "draught," which always accompanies the phenomenon of combustion.

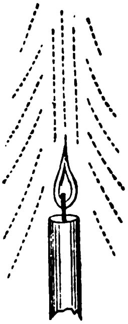
The phenomenon of combustion, under ordinary circumstances, is always attended by a secondary phenomenon, consisting of the production of a "draught" or current of air, which may, however, be almost considered an essential part of the process, as, without it, a continuous combustion could hardly be maintained.

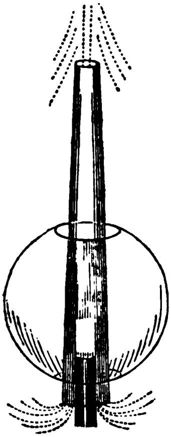
When a fire, or candle, &c., burns in an open space, the air immediately over it becomes heated, and ascends in company with the smoke, if any be present. The surrounding air now closes in to supply its place; this in its turn becomes heated, rises, and gives place to new quantities of adjacent air. The heated air rises rapidly at first, but slowly as it ascends, until it becomes diffused through the surrounding atmosphere.

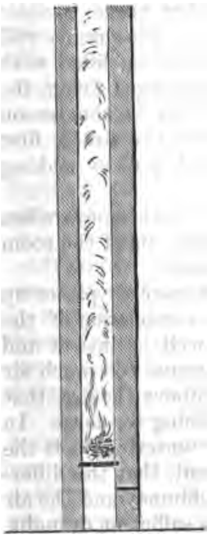
If this phenomenon takes place in a closed space, as in the middle of a room, the heated air rises as before, as far as it can, when, by cooling down, and by the successive additions of more air from the fire, it is again brought adjacent to the source of heat, is heated, and again rises; and so the air circulates, until its chemical condition renders it unfit for combustion.

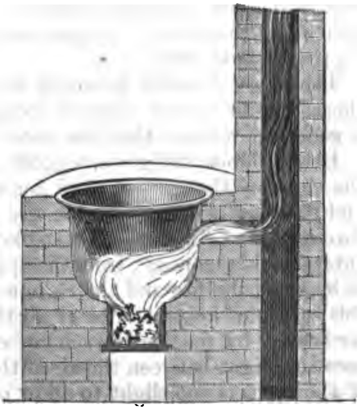
The cause of the air ascending from every source of heat, may be understood if we suppose heat to possess bulk but not weight. Thus, a given bulk of air is greatly increased by being heated, but gains nothing in weight; hence, heated, and therefore lighter air, rises through colder and heavier air (as is well illustrated in the fire-balloon), on the same principle that a cork or piece of wood rises to the surface when liberated under water. The cork or the air is in reality pushed up by the weight of the medium through which it rises.

If we place a chimney over the source of heat, in either of the situations above mentioned, the ascent of air, and in the latter case, its circulation, proceed with greater rapidity, and the more so as we increase the height of the chimney. This is because the heated air and products of combustion remain hot longer (being longer protected









from admixture with the colder air); they are consequently pressed up with greater force by the colder air from beneath.

When the chimney is brought down to the level of the fire, and surrounds it closely, or, for the sake of illustration we may say, when a fire is made in a chimney, the upward current of air is still further increased, because all the air that strives to enter the chimney can only do so through the fire, and of course becomes more strongly heated than if some of it entered at the sides, or over the fire. The air in the chimney being thus more strongly heated, is consequently lighter, and the draught is better, for the reason above stated. We have endeavoured to illustrate the motion of the air and the action of the chimney in the foregoing sketches. Similar results to the above take place if the fire is made in the space we call a room, and a chimney therefrom leads into the open air.

When a fire is made in a common grate, the gases and smoke produced by the combustion rise into the chimney, from the causes above mentioned; but there is little "draught" through the chimney, until the fire is well started, *i. e.*, until the chimney has become filled with warm air, and still better, when, by prolonged firing, the chimney itself has become warm. This is the reason why chimneys sometimes smoke when the fire is first lighted, and may often be prevented doing so by making a good blaze at first.

The slight draught generally found in chimneys when there is no fire under them, is because the air of the room is generally warmer than the external air.

In a common fire-grate, a good deal more air passes up the chimney than is required for the combustion of the fuel; the air passes over the fire as well as into it and through it. Chimneys often smoke because too much air enters in this manner; from the space above the fire, that is, between the fire and the chimney, being too large. In this case, the large volume of air thus entering cools the air heated by the fire to such an extent, that the difference in weight between the air of the chimney and the air of the room is too slight to allow of a sufficient draught.

The plan of preventing chimneys smoking, by placing a plate of iron, and even of a more temporary material, over the space above alluded to, acts by reducing the quantity of air entering in this manner.

It is the air entering in this way over the fire which renders all open ordinary fires more likely to smoke or draw badly than stoves or closed fireplaces; the current of air in the chimneys of the former being always feebler than in the latter case, where no air can enter but through the fire. Thus, in furnaces where a strong heat is required, all openings into the chimney above the fire are closed.

In the best-constructed grates, the fire may "smoke" if not supplied with a sufficiency of fresh air to drive up the chimney that heated by the fire; a result that sometimes happens from the door of the room shutting too closely, or when no proper channel for the entrance of air to the room is provided, as already noticed.

Again, chimneys may smoke from being badly constructed or badly placed in the building. Chimneys built in the outside walls of houses are more liable to smoke than when placed in the interior walls. Again, the draught of chimneys is much influenced by their position with regard to other chimneys, buildings, trees, &c.

COMPARATIVE MERITS OF THE DIFFERENT MODES OF WARMING BUILDINGS, &c.

As mentioned in connection with a former subject, the open fire-grate is, perhaps, the least economical method of consuming fuel; but its many advantages on the score of health are so great, that we have no hesitation in pronouncing it to be the best method, wherever practicable, of obtaining artificial warmth.

With stoves, and other more complicated arrangements of the kind for heating apartments, the air is generally too dry, and more or less impure, not only from an insufficient ventilation, but also from the fact that whatever impurities may be generated in the room are likely to remain there much longer than when a good fire is kept burning in an open grate.

In cases where open fires are inadmissible, or insufficient to warm buildings, the next healthiest means of so doing is by exposed hot-water or steam pipes; these being at a comparatively low temperature, warm the air in contact with and adjacent to them, without burning it, or injuring it to the extent always effected by exposure to strongly-heated surfaces. Several unpleasant and even poisonous products are generated when moist air is brought in contact with strongly-heated iron. For this and other reasons, all contrivances for warming buildings with hot air are highly objectionable.

FUEL.

Before proceeding to consider fire in relation to light-giving purposes, we ought, perhaps, to supply a short description of the various kinds of fuel commonly employed.

Coal, which constitutes the staple fuel of this country for all technical purposes, as well as for the artificial production of warmth, although a mineral, is known to be of remote vegetable origin. The physical characters of coal are too well known to require any notice. Its chemical characters are such as would probably result from the partial destruction of masses of vegetable matter, aided by great pressure and deprivation of air; indeed, geologists have shown it to be the remains of a luxuriant vegetation, which at a remote period flourished on our planet.

Of the various kinds of coal now employed for domestic fires, the Newcastle is probably still the best; the description of coal used in any particular district is, however, of course determined more by the facilities of carriage and consequent cost, than by any peculiarities it may possess. But, as is well known, the cheapest coal is by no means always the most economical.

The quality of coal is governed—1st, by the proportion of carbon and hydrogen it contains. These are its essential constituents, and for ordinary domestic use may be taken as equally valuable; but for certain technical purposes, as for making gas, the relative proportion of these combustible elements is taken into account. 2nd, By the amount and quality of the ash or mineral matter it leaves on burning; these constituents detract from its value, if present in more than a small proportion, and additionally so if they are of a nature to melt easily and form clinkers.

The quantity of ash in some kinds of coal rises so high as to prevent its combustion in ordinary grates; in which cases it can be used only in furnaces, and for inferior purposes, where the purity of the fire is of no moment.

The present is, perhaps, an appropriate place to insert an analysis for showing the composition of coal. The first column may also be taken to represent the general composition of the commoner varieties of coal used for domestic purposes.

COMPOSITION OF COAL.

	Newcastle.	Anthracite.	Wood (Beech).
Carbon	80·0	91·0	49·0
Hydrogen	6·0	3·5	6·0
Oxygen	8·0	2·0	43·0
Nitrogen	·7	·5	·5
Sulphur	·3	·5	—
Ash	5·0	2·5	1·5
	100·0	100·0	100·0

Thus, besides the before-mentioned abundant constituents of coal, there also occur, in smaller quantity, sulphur and nitrogen, &c. These are converted into volatile products during the combustion of the coal (the former of these occurs in the coal as iron pyrites, constituting the metallic-looking scales often perceptible in coal). The unpleasant, suffocating smell of coal-smoke is, for the most part, due to this impurity. The nitrogen combining with hydrogen, passes off in the form of ammonia, or hartshorn, and is retained, to some extent, in the soot, which thus becomes useful as a manure. Most of the hartshorn and its compounds, or, to speak chemically, the salts of ammonia, such as sal volatile, sal ammoniac, &c., are obtained from the nitrogen present in coal.

In burning coal in common grates, a large quantity of it is converted into cinders, which are often allowed to be thrown away with the ashes. In all cases, however, where economy is an object, these should be saved, as, by so doing, a saving of about 15 per cent. of coal may be effected. Moreover, for some purposes, cinders (which are, in fact, lightly-burned coke) are preferable to coal, since they give a steadier temperature on burning. To poor persons especially, cinders, and even ashes (so-called), are useful fuel; as, when mixed with vegetable refuse, they may be burnt until all the carbon is consumed.

Coke is simply a more extensive kind of cinder, since it consists of coal deprived of its hydrogen or flame-producing constituent, with a portion of its carbon, by having been exposed to heat without access of air. Coke consists of carbon, with most of the mineral constituents of the coal from which it has been made, and from its almost vitreous character, is difficultly combustible, and advantageously burned only in closed fireplaces. On this account, coke can seldom be made use of for domestic fires; but the same property renders it valuable in cases where a very intense and long-sustained heat is required,—as in locomotive engines.

Wood, undoubtedly, makes the most cheerful and pleasing kind of fire for purely comfort-promoting purposes; but its great price, and certain inconveniences attending its use, prevent its being used to any extent in this country, although the occasional addition of wood to a coal fire in living-rooms is a practice now becoming common. The superior cleanliness of a wood fire, and the agreeable smell it diffuses, added to its peculiarly pleasing manner of burning, are qualities greatly in its favour; but the low price of coal, and its more steady and lasting combustion, of course make its use generally preferable.

The ash of wood is of an entirely different nature to that of coal: while the latter consists of earthy matter admitting of no useful application, that of wood is exceedingly rich in a valuable alkali—potash. This substance has been already noticed in the preceding chapters, and is a substance of considerable importance: the large quantities of it required are all obtained from the ashes of wood, which, in those parts of the world where it at present constitutes an encumbrance, is burned in wholesale quantities for the sake of its ashes.

Potash is also required in large quantities by cultivated plants, as is evident from the facts pointed out in speaking of the mineral elements of food: hence, wood-ashes are also a valuable manure. A copy of the analyses of these two kinds of ash may not, perhaps, be uninteresting:—

COMPOSITION OF COAL-ASH AND WOOD-ASH.

	Coal-ash.		Wood-ash.
Silica	61·50		1·20
Oxide of iron and alumina	26·72	Oxide of iron	·60
Magnesia	1·70		—
Lime	2·05		47·20
Potash	trace		11·80
Soda	trace		2·04
Phosphoric acid	·30		3·29
Sulphuric acid	5·72		1·70
Carbonic acid	2·01		32·17
	100·00		100·00

Charcoal bears the same relation to wood as coke does to coal; but since wood parts with its hydrogen much more readily than coal, and is naturally much purer, the residue left after partial burning, as charcoal, constitutes a very superior fuel, as regards domestic appliances, to coke. From the extreme facility of kindling, its steady heat when burning, and its manageableness, added to the perfect cleanliness and purity of its combustion, charcoal is highly prized for all operations where the heat has to be very carefully applied. For these reasons, as is well known, charcoal is largely employed in cooking. It is also largely used in chemical laboratories for the same useful properties, besides numerous other purposes in the arts.

By the modern process of making charcoal, viz., by distilling the wood in closed vessels, there are also obtained acetic acid, or vinegar, pyroligneous ether, or "wood-spirit," now largely used in place of spirits of wine, and also for "methylating" the latter, as mentioned in a previous chapter; also creosote (used as a very disagreeable, though often effectual, remedy for toothache, and for preserving timber from rotting); and a host of other less-valued products. A great deal of charcoal is, however, still prepared on a small scale, by burning the wood in stacks covered with earth, and, after all volatile products are expelled, extinguishing it by closing all communication with the air.

Charcoal is scarcely adapted for heating apartments, even in common grates, neither would its price allow of its use in this way. Although the supposed advantage of its giving no smoke has led to many sad disasters to persons, who, having foolishly made use of it for warming chambers in which there was no chimney, have fallen victims to their own ignorance,—these results arise from no poisonous properties of charcoal, as is sometimes supposed, but from the carbonic acid and carbonic oxide gases generated by its combustion. The same result would follow the use of coal, or any other fuel, in the same manner, were it as combustible as charcoal; or, were it not that the unpleasant-smelling and visible products of its combustion would sufficiently protect the most ignorant persons from the effects of these more insidious gases.

FIRE AS A SOURCE OF LIGHT.

We have now to speak of fire as a source of light. This part of our subject will perhaps be best understood if we first direct attention to coal-gas, as, apart from the fact of this agent being at present probably the most extensively-employed source of light, a knowledge of its properties will give a good insight into the philosophy of other minor luminaries. In oil-lamps, candles, &c., the light obtained is derived from inflammable gases, closely analogous, if not identical, with the combustible portions of coal-gas. Indeed, other materials than coal, such as oil, resin, tallow, wood, &c., are often used on a small scale for preparing illuminating gas, which varies but slightly from that made of coal.

In speaking of coal as a fuel, we remarked that the flames it gives rise to during the early stages of its burning, are due to the combustion of its hydrogen with a part of its carbon. We may now add, that if coal be heated in closed vessels, similar compounds are generated, which, being permanent gases, like those of the atmosphere, admit of conveyance to a distance in pipes.

In making coal-gas at gas-works, the coal is heated in retorts set in a furnace, which is fed with the coke left in the retort after its flame-producing materials have been expelled. The quantity of gas thus obtained, and its quality, depend chiefly on the temperature and mode of conducting the process. In large gas-works, as those which supply London and other large towns, this process is conducted on a very large scale, the number of retorts in some works amounting to several hundreds. These are kept in constant use, the retorts being charged as often as necessary, an operation demanding manual labour of the most laborious and unwholesome kind. 1 lb. of good coal produces about 4 ft. of purified gas, a quantity which is consumed in an ordinary gas-burner in about an hour and a half.

The gas as it issues from the retorts consists of a mixture of gases totally unfit for illuminating purposes. Although the greater part consists of inflammable gases, consisting of hydrogen combined with carbon, as above mentioned, it also contains several other gases, some of which are poisonous, and must be removed before the gas becomes usable. The purification of coal-gas is effected by a variety of processes, which need not here be described.

Although coal-gas, as now prepared by the most improved method of manufacture, is very pure compared to what it was some years ago, nevertheless it still contains certain impurities, as, for instance, sulphide of carbon, which escape the means of purification at present employed. This and other compounds, present in variable quantity in coal-gas, render it a less wholesome source of light for domestic purposes than other less-powerful luminaries, as the above impurity, by burning, is converted into sulphurous acid, the objectionable qualities of which have been already pointed out.

The essential constituent of coal-gas is carburetted hydrogen, known to chemists as olifiant gas, and also as heavy carburetted hydrogen, to distinguish it from a much less valuable but analogous compound, which also occurs in coal-gas: this second gas is called light carburetted hydrogen, or marsh gas.

COMPOSITION OF COAL-GAS (BY MEASURE).

Olifiant gas (heavy carburetted hydrogen)	13
Light ditto (marsh gas)	83
Carbonic oxide	2
Hydrogen	1
Nitrogen	1
	100

With traces of carbonic acid and bisulphide of carbon.

Light carburetted hydrogen is so called in comparison with the second gas of the same character, which is heavier, bulk for bulk, or is much richer in hydrogen and carbon. The former gas burns only with a feebly luminous flame, while the heavy gas burns with a clear white light. This latter gas does not occur in a separate state in nature, but is always formed when tallow, wax, &c., are heated at a certain temperature: it is also produced in smaller quantities from coal; the better kinds of coal yielding most of this gas. The light carburetted hydrogen occurs in nature, and is even believed to exist in minute quantities in the atmosphere; as already mentioned, it is called "marsh gas," because it is formed from decayed leaves in marshy and damp places.

The inflammable gas which in some places issues from the earth on our boring into it, especially in peaty districts, consists for the most part of light carburetted hydrogen. It is also known by another and ill-omened name—"fire-damp," which, generated spontaneously from the coal, is apt to accumulate in the cavities of the mines, and give rise to those disastrous explosions which so frequently cause the death of the poor coal-miner.

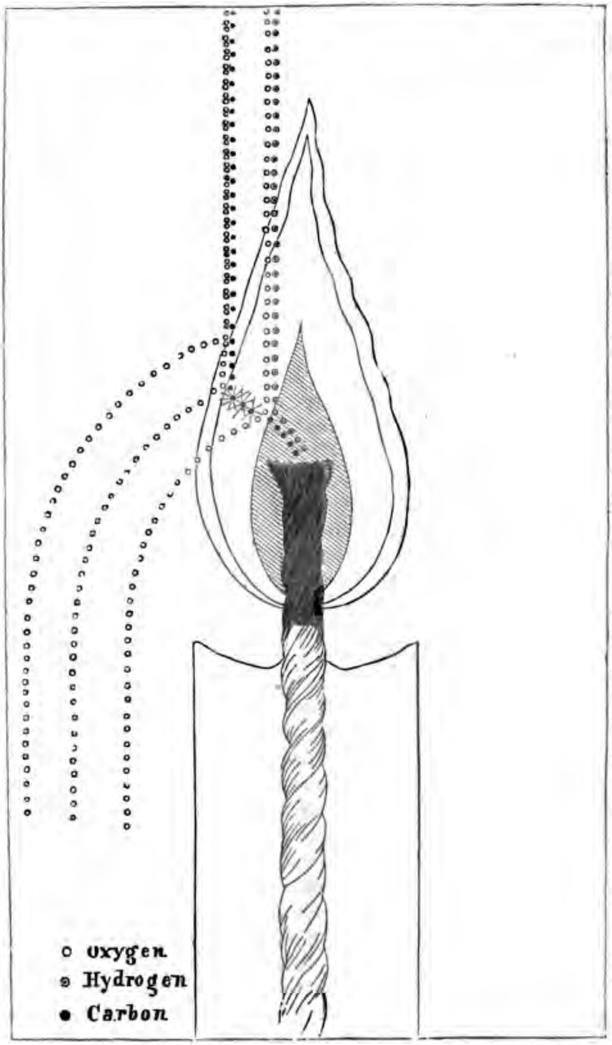
PHENOMENON OF FLAME.

In speaking of hydrogen, we remarked that this gas is the basis of all the flames commonly met with. Now, hydrogen alone burns with a pale flame, scarcely visible by daylight, but of intense heat. When hydrogen is combined with carbon, as in the gases above spoken of, it burns with diminished heat, but greatly increased light: hence, the presence of carbon has in this instance given rise to this new phenomenon. In the combustion of carburetted hydrogen, as in coal-gas, the hydrogen burns first, in virtue of its superior inflammability, while the carbon is separated in a chemically divided state, and, being suspended in the flame produced by the burning hydrogen, becomes strongly heated, in fact white-hot, and in this condition gives rise to the phenomenon of light.

It is only while the carbon is suspended in the substance of the flame that it is luminous; as soon as it reaches the extremity of the flame, or, in other words, as soon as it comes in contact with the oxygen of the air, it also burns, and passes off invisibly. The carbon, however, is not at once converted into its ultimate product,—carbonic acid; but first becomes carbonic oxide, which, being an inflammable gas, burns with a pale blue flame (which may be seen inclosing the yellow flame of ordinary lamps and candles), and is thus converted into carbonic acid.

The structure of the luminous flame will perhaps be better understood by reference to the adjoining diagram, which I designed to illustrate the successive changes carburetted hydrogen gas (the essential agent in all common flames) undergoes during combustion.

If it be asked what is the cause of light, or why heat is thus apparently converted into light through the agency of a solid, we must frankly admit that we do not know. Up to the present time none of us knows anything definite about the origin of light; we know a great deal about its effects, and the conditions for its production from the artificial sources commonly used; but of the manner in which it is produced from a lamp or


○ Oxygen
◎ Hydrogen
● Carbon

candle, for instance, we are very ignorant. All we can say of it is, that it is fire, somewhat modified.

It is better to admit this than to attempt to account for the production of light by any of the elaborate theories which have at different times been advanced in explanation of this phenomenon, most of which, up to the present time, fail to give any satisfactory explanation of the phenomenon. The only promising theory of the production of light is that suggested by Mr. Grove, in his "Correlation of Forces."

The chief condition for the elimination of light is that some solid be strongly heated. In the example we have mentioned, the solid is carbon, which, when strongly heated in the hydrogen flame, emits light. But the elimination of light at a high temperature is by no means peculiar to carbon, although, in all artificial sources ot light, carbon is the only solid that takes part in the process. But similar effects attend the elevation to a high temperature of several other solids. One of the most powerful lights we can produce is obtained by heating very strongly a small piece of lime. The heat required for this purpose has to be very intense, and can only be obtained by means of the oxyhydrogen blowpipe, an apparatus contrived for urging a hydrogen flame with pure oxygen, by which the strongest heat at our command is obtained. This beautiful light is called the Bude and Drummond light, and is also known as the lime-light.

Quite recently, this light, somewhat modified, has again been brought forward by a company for ordinary illuminating purposes; but the great attention and care demanded for its successful employment will probably ever stand in the way of its being generally adopted.

The equally beautiful electric light will probably also, for the same reason, ever be confined to very limited use, even though it is now nearly perfected, as we may infer from its having been adopted by the Trinity Board as a light to be depended on for lighthouses. The electric light lately erected at the South Foreland lighthouse is probably the commencement of a new era in lighthouse illumination, for which purpose this light seems to be especially adapted.

Coal-gas is, without question, the cheapest and most convenient source of light in all cases, and for shops and public buildings in large towns, has now become almost indispensable. Nevertheless, coal-gas possesses certain disadvantages, especially as an illuminating agent for private dwellings, which render it inferior, in many respects, to oil-lamps and candles; but, as these latter sources of light, oil-lamps especially, demand some little trouble and skill in their use, of which gas is entirely free, it is rapidly becoming common in private houses.

One of the disadvantages attending the use of gas, especially in private dwellings, is a more than possible danger from explosion. The more or less serious gas-explosions heard of from time to time sufficiently prove that the use of gas is not altogether unattended with danger; indeed, unless its management can be wholely intrusted to one responsible person, its introduction into a dwelling-house is, to say the least, unadvisable.

All inflammable gases, including coal-gas, explode when mixed with sufficient air to allow of combustion, which, under these circumstances, takes place at every part of the mixture simultaneously, and the resulting heat, by greatly expanding the products of combustion, produces the violent expansion which we call explosion. A great deal of gas may be mixed with air without its producing an explosive mixture, the gas being too much diluted to allow of the extension of its flame; but when the proportion of gas amounts to $\frac{1}{15}$th, the mixture then becomes explosive.

This proportion of gas in air is the least at which explosion can occur, and the result is much less violent than when the mixture consists of gas and air in equivalent proportions; *i. e.*, the proportion in which they unite when burnt under ordinary circumstances. The most explosive mixture formed of coal-gas consists of one part gas and ten parts air.

Precautions against explosions of coal-gas are, of course, more necessary in private dwellings, from the usually smaller size of the rooms or other spaces where the gas can accumulate, and their imperfect ventilation, compared with shops and public buildings: hence, a neglected escape of gas will sooner produce an explosive mixture in the former case than in the latter.

A room containing 1,000 cubic feet of air would become filled with an explosive mixture in twenty hours from a burner which liberated 4 feet per hour (as from a common burner left full open, but not lighted).

A much shorter time than this would be sufficient to render such a space dangerous; for the reason that in a still atmosphere, coal-gas, from its lightness in comparison with the air, tends to accumulate at the upper part of the chamber (notwithstanding the law of diffusion), where an explosive mixture might be found, while the lower portions of air were comparatively free from gas.

The majority of gas explosions are attributable to the simplicity of ignorant persons, who, having discovered a strong escape of gas by their noses, instead of throwing open all doors and windows, as common sense would point out, seek to verify the fact by bringing a light.

We may add by the way, that it is similar mixtures of gas and air which give rise to those distressing colliery explosions unfortunately so common and so little thought of. The terrible effects in these cases are traceable to the unyielding nature of the spaces where the explosion takes place.

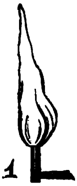
Another disadvantage connected with the use of gas in private houses, is its liability to vitiate the atmosphere of our rooms to an unwholesome extent. We are apt to forget that the larger amount of light at our command, entails a corresponding increase in the consumption of air; and unless a good supply is provided, the atmosphere of a room where gas is burnt becomes unwholesome much quicker than when any less vigorous luminary is employed. A gas-burner consuming 3 feet per hour consumes about 30 feet of air, and produces about 3½ feet of carbonic acid gas. This is about as much carbonic acid as is produced by seven persons. This matter is more necessary to be attended to in cases where the gas employed is deteriorated by the impurities already spoken of.

A composite candle (a common dip consumes rather more) consumes about 5½ feet of air per hour, and produces 511 cubic inches of carbonic acid.

Much annoyance is sometimes endured from the escape of gas; its presence in an uncombined state in the air of our apartments, being, to say the least, exceedingly disagreeable. It is often difficult to get gas-fitting done as it should *only* be done; *i. e.*, with all joints, taps, &c., perfectly gas-tight,—a result less common than generally supposed.

The common test for ascertaining the presence of a leak in gas-fittings, by means of a lighted match, is an exceedingly rough and imperfect one, as is known to every one who has had an opportunity of witnessing how much of any inflammable gas it takes to support even the smallest flame.

The character of coal-gas as an illuminating agent is much influenced by the kind of burner we burn it at. For a long time, the simple jet was used (No. 1), or a combination of these (No. 2), as seen in the street-lamps of London not many years ago. The Argand, or ring-burner (No. 3, to be described in connection with oil-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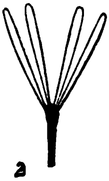
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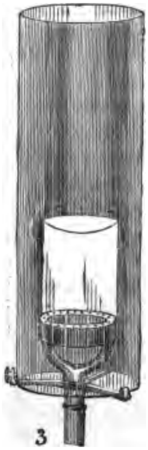
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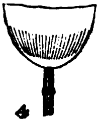
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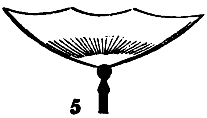
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lamps), was next employed, with better result, the light thus obtainable being good, but requiring a large consumption of gas, and the corresponding amount of heat generated constituted a serious objection in many cases, although this form of burner, variously modified, is still extensively employed for many purposes.

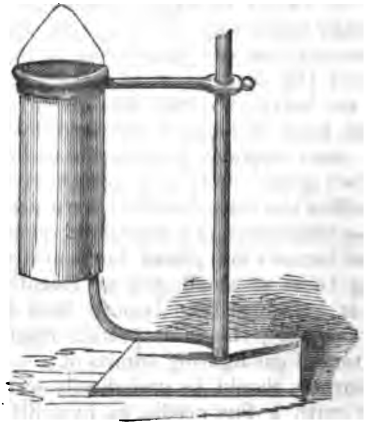
Another gas-burner, approaching near to perfection, is technically called the "bat-wing" (No. 5), and consists of a hollow nipple, having a fine slit across it, through which the gas issues in a flat jet, producing, when lighted, a broad blade of flame. A drawback belonging to this burner is, however, its liability to get out of order by the slit referred to becoming partially filled up with rust or dirt, by which the flame becomes broken up into all kinds of unintended shapes.

The kind of burner now most commonly employed is that technically called the "fishtail" (No. 4). As in the preceding burner, the gas burns from it in a thin sheet of flame; but the combustion is more perfect and uniform, and the burner is much less liable to get out of order. This kind of flame is obtained by making two jets of gas meet opposite to one another in a little cup, when the two spread out into a thin sheet of gas, which in burning offers the best conditions for a perfect combustion, and the elimination of a maximum quantity of light. When these burners are placed horizontally at the ends of radiating tubes of small size, as recently adopted in a few public buildings (St. James's Hall for instance), we obtain, probably, the most perfect result which the present system of gas-lighting admits of.

All gas-burners should be periodically screwed off, and cleared out with a fine needle, as, by a little trouble in this way, a great deal of annoyance from unequal light or smoky burners may be avoided.

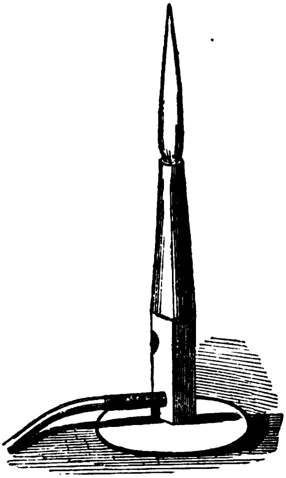
Gas is also employed, to a considerable extent, as a source of heat for warming apartments, cooking, &c. Its use for these purposes is attended with many advantages, of which freedom from dirt, and complete control of the heat, are, perhaps, the greatest, especially in delicate operations; but, on a large scale, these advantages are counterbalanced by the commonly primary consideration of expense; so that, unless the price of gas should become very much reduced, its use in this way can scarcely be expected to become general.

Gas becomes best adapted for heat-giving purposes when mixed with air before burning; this is generally effected by an excellent contrivance, called the "gauze burner" (No. 1). It consists of a hollow upright cylinder, the upper end of which is covered with wire gauze; the lower end is open, through which air can freely enter, and mix with the gas, which is admitted to the cylinder by any convenient pipe opening into it beneath the gauze. The mixture of gas and air rises through the gauze, and when lighted, burns with a pale blue flame, of strong heat, resembling, indeed, the flame of a spirit-of-wine lamp.



No. 1.

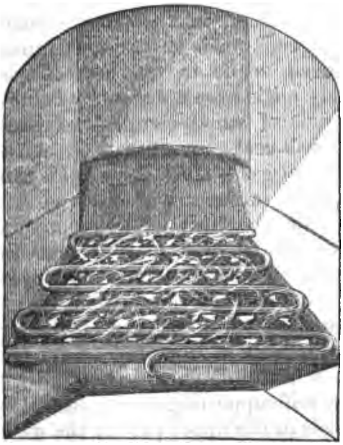
Another gas-burner, now much used for similar purposes, is one invented by Professor Bunsen, but is patented by a gas-fitter in Holborn. This burner (No. 2) consists of a jet of gas, through which a stream of air is self-impelled, the flame produced being even hotter than is obtained by the burner above described. Such a flame has long been known, but, as was supposed, could only be produced



No. 2.

by an artificial current of air; this, however, is in the new burner dispensed with. Arranged in bunches, these burners give almost any heat desired.

Various attempts have been made to make use of gas for domestic fire-grates: by means of it, "unconsumable" fires may be obtained. On heating certain solids with gas, they become red-hot without undergoing any further change. Such a substance is asbestos, or amianthus. Although a mineral, this substance occurs in fine filaments like cotton or wool, and, when heated in a fire, glows, but is not consumed. In the inventions of this character, the asbestos is spread over a grating or iron support, which fills the grate, and is kept red-hot by gas jets placed beneath it (No. 3). We believe a plan has lately been suggested for employing coke in the same manner. The dust and dirt consequent on the removal of ashes, &c., as in a common fire, are by this means avoided, as well as all unnecessary consumption of fuel, with other advantages.



No. 3.

Yet fires of this description are of course deficient in the peculiarly cheerful appearance of open fires that need replenishing. Moreover, such fires especially fail, in not requiring poking,—an important matter, we suspect, in the eyes of most Englishmen.

We ought here perhaps to mention that that class of gas stoves which possess the alleged great advantage of "requiring no flue," except in very rare instances, are wholly inadmissible; since, as we have seen, the products of combustion bear a direct proportion to the warmth obtained, and a sensible increase of temperature obtained in an ordinary-sized chamber by this means must necessitate the vitiation of the air to an unwholesome extent.

We may now proceed to direct attention to those luminaries of lesser magnitude; viz., lamps and candles.

OIL-LAMPS AND CANDLES.

The chief difference between gas-lamps and the sources of light we have now to consider, is, that in the latter case the carburetted hydrogen is made on the spot, immediately before it is required, while in the case of gas-burners, it is brought ready made from a distance. Tallow, wax, and all other materials of which candles are made, may be regarded as solidified coal-gas—or rather, as the solidified essential gases of coal-gas,—since these solids contain none of the objectionable impurities of coal-gas.

On first lighting a candle, the heat applied converts some of the finely-divided tallow, or analogous material diffused through the wick, into carburetted hydrogen, and heats it sufficiently to allow of combustion taking place between its constituents and the oxygen of the air. By this combustion, enough heat is liberated to convert further quantities of tallow into inflammable gas, quickly enough to make the process self-supporting, while the tallow lasts. This process proceeds in the upper part of the wick, where it is enveloped with flame, the melted tallow, &c.,

being drawn up through the wick, by the force of capillary attraction.

The further changes which the inflammable gas undergoes during its combustion, are precisely similar to those we have already pointed out in describing the structure of flame.

Many of the materials commonly used at the present time for making candles are extremely beautiful, and equal, if not superior, to the best material formerly at command—namely, wax. Thus stearine and parafine make candles almost equal in quality and superior in appearance to wax; while the inferior kind, know as "Composites," consisting of stearic and margaric acids, &c., have almost entirely superseded the old-fashioned tallow mould, to which they are greatly superior.

Parafine is made from peat, and may be regarded as artificial wax. When dry, peat is subjected to dry distillation; *i. e.*, is heated in closed vessels, as coal is heated in making coal-gas. Parafine is one of the products thus generated, but requires to pass through a lengthy process for its purification. It is these drawbacks which render this beautiful material at present so expensive, although, we believe, it is still slightly cheaper than wax. As the source of this material is practically inexhaustible, there is every reason to expect that the process of preparation will be, sooner or later, simplified, so as, by reducing the price of the material, to allow of its more general use.

Ordinary composite candles are prepared from palm oil, and cocoa-nut oil, as well as tallow, by a very ingenious process, chiefly carried on at the works of Price's Candle Company, at Vauxhall. The process is, however, too complicated to allow of description here. We may remark, however, that the candles consist chiefly of stearic acid, also of margaric and oleic acids, variously modified by heat.

We have already mentioned, in a previous chapter, the nature of these acids, and that oils and fats bear a distant resemblance to salts; that is to say, they consist, for the most part, of an acid (stearic, oleic, &c.) combined with a substance analogous to the base in salts, called glycerine.

The more expensive candles consist of almost pure stearic acid, which, thus prepared, exhibits the beautiful pearly character so much admired in the so-called sperm candles.

Perhaps the greatest modern improvement in candles is the discovery of a simple means of avoiding the necessity of snuffing.

The accumulation of snuff in the wicks of common candles is caused by the carbon of the wick not getting sufficient oxygen to oxidize it, owing to insufficient heat and its being inclosed by the flame. The above end is effected by using thin wicks, tightly plaited, so that the liberated end shall curl round, and thus be brought in contact, while hot, with the air. This result is sometimes assisted by impregnating the wicks with borax and other materials.

In oil-lamps, the combustion proceeds in a manner closely analogous to that which goes on in candles; but as the mechanical peculiarities of lamps allow of a larger flame being used, we obtain from them a brighter and more powerful light than can be obtained from candles.

The greatest improvement ever made in oil-lamps consisted in the introduction of the double current, or Argand burner; so called from the name of its inventor. This improvement is based on the idea of supplying air to the interior of the flame as well as the exterior : with this object, the wick is made cylindrical, and supported in such a manner as to allow the air to pass freely up the middle. By this means a circular flame is obtained, which, when covered by a glass chimney, an essential part of the arrangement, offers every condition for a very perfect bustion.

The French moderator lamps, now so much used, are on this principle; although other minor improvements help to make them the best kind of oil-lamp, and, perhaps, of illuminating agents generally, for domestic use.

The oil now employed for oil-lamps is, for the most part, vegetable oil. For a long time, the best animal oil (sperm oil) only could be employed for this purpose; but as this became scarce, means were sought for of rendering vegetable oils available.

A plan of making vegetable oils fit for use in lamps, was found to consist in agitating the oil with sulphuric acid, and afterwards allowing it to settle for some time. Thus treated, the oil loses the water and vegetable juices always mixed with it, while other impurities become charred, and settle on standing. The colza oil now so extensively used in moderator lamps, which has, indeed, almost superseded whale oil, is prepared from the seed of a species of cabbage, now extensively cultivated in the south of France for this purpose.

The naphtha and camphine lamps brought forward from time to time have, in general, proved failures, not only from their well-known liability to give off "blacks," or to produce unpleasant smells, but also from their liability to explode; more than one serious accident having occurred from this source. The vapour of camphine (which is simply purified turpentine), and all similar liquids, explodes, like the gases already mentioned, when mixed with air in certain proportions: hence, lamps of this description are likely to become filled with an explosive mixture when allowed to stand for any length of time but partly filled.

The great economy connected with the use of these lamps, and their undoubted superiority as regards brilliancy of light, would be great temptations to their use if the above-mentioned disadvantages at present belonging to them could be entirely overcome.

All ordinary flames, and other forms of combustion, depending on the air for the oxygen they require, are immediately extinguished if by any means they are deprived of a supply of air. We might often prevent the ravages which fire too often causes when it gets loose from us, had we the presence of mind to apply this fact; a burning body being, as is well known, instantly extinguished, if by any means it can be shut up from the air by wrapping it even in other materials. The sad accidents lately so prevalent, of ladies' dresses catching fire,* is a sufficient reason for our trying to impress

* We ought, perhaps, to mention, that certain salts have the effect of rendering muslin and other fabrics much less inflammable:

this fact on the memory; especially as, since ladies will persist in wearing dresses that expose them to these mishaps, there is no knowing how soon its prompt recollection might not afford an opportunity of changing a probably serious accident into a possibly agreeable incident.

The extinction of fire by water is the consequence of the rapid reduction of temperature, or withdrawal of heat, which water, by its evaporation, gives rise to. In small quantities, water often invigorates rather than checks fire; indeed, by special circumstances, water may actually be made to contribute to the combustion of coal fires; a fact which the common practice of wetting coals for economy's sake (although possesisng another advantage in preventing dust), and for increasing the heat of the forge-fire, tends to support.

Combustion may, however, proceed, independently of the air, provided oxygen is supplied from any other source. We may mention, by the way, that combustion may even take place without oxygen; since this phenomenon attends the energetic union of other chemical elements.

The combustion which first starts a lucifer-match or "vesta" is an instance of combustion independent of the air. The chlorate of potash, which the heads of all matches contain, furnishes the oxygen required. Moreover, the large proportion of oxygen which this salt contains, renders it capable, in the presence of an easily inflammable solid, such as phosphorus (which matches also contain), of setting up a rapid chemical decomposition, which results in the production of fire, even by the slight increase of temperature consequent on the friction we use to ignite them.

Another still more striking instance of combustion by oxygen, but independent of the air, is furnished by gunpowder and all allied pyrotechnic mixtures. In these cases combustion still consists in the rapid union of inflam-

the salts suitable for this purpose are alum, sal ammoniac (chloride of ammonium, &c.). Another salt lately found to be most efficacious in this respect, and to possess the advantage of not washing out when once impregnated, is tungstate of soda; but the present high price ot this salt will probably preclude its extended use in this way.

mable matter with oxygen; but the oxygen is furnished from an internal source, viz., from the nitre which all such mixtures contain, and which is nearly as rich in oxygen as the chlorate above mentioned.

Combustion of this kind cannot easily be extinguished by mechanical means, nor by wind; or even, when inclosed in cases, by water. Upon this circumstance chiefly depends the invaluable service of these mixtures in cases of shipwreck and danger at sea. Rockets, blue-lights, &c., being of this nature, burn with unabated vigour in the fiercest wind or rain.

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